National Marine Fisheries Service, Advanced Sampling Technology Working Group, Study Group EK (SG-EK) Workshop Report
August 29, 2004

EXECUTIVE SUMMARY

A workshop was convened July 15-16, 2004 at the Alaska Fisheries Science Center (NOAA/NMFS) to develop procedures for characterizing and comparing measurements and analyses by the EK500 and EK/ER60 echo sounders and post-processing software systems. The objectives of this workshop were to discuss and define metrics, review prior and on-going comparisons and measurements, and to develop an experimental design for future work with the EK/ER60 that includes verification and recommendations for measurements and survey practice. This workshop marks the beginning of an effort to bring together fisheries acousticians within and outside of NOAA to discuss current measurement protocols and to foster collaborations among users of the Simrad echo sounders. Representatives from Simrad and Echoview were invited to review and provide detailed technical information and to improve communication with industry. The intent of the SG-EK is that these collaborations and efforts will continue in the future to enhance communication among NOAA/NMFS science centers, the scientific community, and industry.

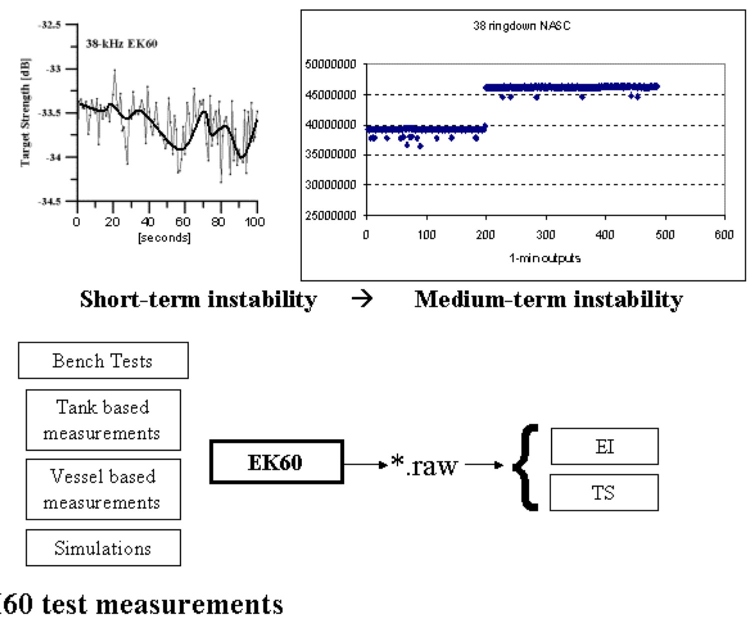

Figure 1. Illustrative representation of potential concerns with system performance and stability (upper panels), test measurement categories (lower left), and data flow and essential data products (lower right). Upper panels display target strength measurements during a calibration trial (note: solid line was drawn by eye) and step in s_A values observed during a survey. [Figure courtesy of R. Kieser and M. Jech]

Eighteen representatives of NMFS Science centers, academia, industry, and other governmental agencies attended the workshop (see attendee list in the workshop minutes). Five presentations highlighted prior and on-going measurements and simulations evaluating the EK/ER60 and comparisons to the EK500. Discussions focused on an in-depth understanding of the EK/ER60 measurement process, on measurement issues, desirable enhancements and future experiments and collaborations.

The EK/ER60 is a significant advancement in scientific echo sounding. The transceiver electronics are state-of-the-art, operational software is personal computer based, calibration is integrated with operations, and the system allows remote control, via Ethernet, of echo sounders and echogram displays. While the EK/ER60 is a significant improvement, primary concerns of system performance and stability were emphasized during the workshop (Fig. 1). Laboratory measurements with 38-kHz EK60 Mark I systems show increased target strength variability relative to the EK500 and accepted standards (M. Jech and K. Foote), and a number of large gain steps have been observed during survey operations (N. Williamson). In addition, critical shortcomings in Simrad's documentation of algorithms and signal processing methods have been identified. This group considers these and other issues part of the introduction and acceptance of a new scientific instrument to an appreciative but discerning audience. The group is convinced that the process of resolving these issues will yield the best possible results and much would be overlooked without a critical evaluation.

Workshop attendees were in unanimous agreement that the EK/ER60 user community should work cooperatively with Simrad and other third-party software developers to advance echo sounder system performance, signal processing, and data analyses with the goal of improving the accuracy and precision of acoustically derived fisheries estimates. The meeting has enhanced existing good rapport with Simrad, and progress in defining an approach to resolving these issues has been made.

Throughout the workshop, a set of overarching recommendations emerged as essential to moving forward with evaluating the EK/ER60 as the principle echo sounder for scientific surveys. These recommendations are:

- All algorithms used by the EK/ER60 need to be described in detail and documented.
- All parameters used by the EK/ER60 need to be defined, documented, and included in the output data as metadata.
- EK/ER60 hardware and software version numbers need to be included in the output data as metadata.
- EK/ER60 hardware and software version numbers need to be stated when users report issues with the echo sounder and software.
- Revisions to hardware and software need to be documented.

Documentation needs to be reasonably self-contained rather than references to earlier documentation or correspondence, and documentation should be in electronic form and part of the distributed EK/ER60 hardware and software. The group realized the potential proprietary nature of some hardware and software developments, but anticipate that algorithms and parameters that are relevant to the researcher can be provided.

Specific issues with the EK/ER60 that were highlighted during the workshop are detailed in this report. The issues are stated with a brief discussion and recommendations for additional measurements and activities. Discussion sections are necessarily brief, and full details can be found in the minutes from the meeting or by contacting the SG-EK.

INTRODUCTION

The Simrad EK500 scientific echo sounder (Bodholt et al., 1989) is a standard echo sounder used for fisheries applications throughout the world and has been used by the National Marine Fisheries Service (NMFS) for more than a decade to survey a number of fish populations. Data post-processing was generally performed with the Simrad BI500 software, but this tradition has given way to post-processing software solutions including SonarData's Echoview and very recently the Simrad BI60. The Simrad EK60 scientific echo sounder is the next-generation system (Anderson, 2001). The EK60 is compatible with both Echoview and BI60 post-processing software. Since introducing the EK60 in 2000, Simrad has revised the control and processing software several times (current version is ER60 V2.0.0) and is phasing out the EK500 echo sounder.

Maintaining high-quality time series of density and abundance estimates of marine fish stocks is a goal of fisheries managers. The transition to a new echo sounder system requires comparison of measurements and data post-processing results from both systems. Differences in the measurements and data post-processing must be quantified to evaluate their potential effects on population estimates derived from acoustical measurements.

The goal of the EK500 and EK/ER60 study group (SG-EK) is to quantify effects of transitioning from the EK500 echo sounder to the EK/ER60 echo sounder and associated post-processing software on acoustically derived abundance estimates by:

1) Characterizing and comparing measurements of the Simrad EK500 and EK/ER60 echo sounders;
2) Characterizing and comparing data analyses with the Simrad BI500, BI60, and Echoview post-processing software systems;
3) Recommending amendments and modifications to the national and regional acoustic protocols for the EK/ER60 as the replacement for the EK500; and
4) Maintaining a dialog with manufacturers to assure accurate interpretation of their materials and measurement results, and to identify and facilitate improvements where necessary.

Realizing these goals will require cooperation and collaboration among NOAA-Fisheries science centers and state, federal, international agencies and institutions, Simrad, SonarData and other 3rd-party software developers.

WORKSHOP TOPICS

Calibration Methods

Purpose:

Calibration is a measure of system performance, ultimately to express acoustic measurements in physical units for quantification of biological organisms. The primary quantities of interest are accuracy and precision in both target strength (TS) and volume backscattering (S_v) measurements.

Standards:

Calibration standards for acoustic measurements as applied to fisheries applications have been developed over the past two decades (Foote et al., 1987). These standards provide a guideline for evaluating echo sounder performance and stability. Representative standards at 38 kHz are:

- On-axis accuracy: ±0.1 dB
- On-axis long-term precision: ±0.5 dB
- Beamwidth accuracy: ±0.1 degree
- Equivalent beam angle accuracy: ±0.5 dB

Accuracy refers to the measured accuracy relative to the true value of the calibration target, beamwidth or equivalent beam angle. 'On-axis long-term precision' refers to the stability of the echo sounder over longer time periods of months to years.

Measurements:

Measurements obtained during standard sphere calibration include on-axis sensitivity (TS and volume backscatter (S_v)), beam pattern and beamwidth, split-beam angle sensitivity, and alignment between split-beam angle measurements and the transducer's acoustic axis. These are often done by means of the split-beam functionality of the system, if available, but with the penalty of having to rely on angle determination by the very system that is being calibrated. A better method is to measure the angles independently of the system being calibrated. Absolute estimates of these parameters are required for complete system evaluation and comparison, and have been obtained for the EK500 and EK/ER60. Initial and periodic echo sounder and transducer evaluations also should consider the equivalent beam angle, range compensation, and system linearity, dynamic range, and noise characteristics.

On-axis sensitivity as a time series

The acoustic axis is the point of maximum sensitivity within the acoustic beam, and on-axis sensitivity defines the overall echo strength compensation gain. Calibration exercises are conducted over short time periods of minutes to hours.

Beam pattern

The transducer beam pattern is used to compensate echo strength for target angular location in the acoustic beam and in deriving the equivalent beam angle (Ψ). Measures of the beam pattern, beamwidth, alignment of the acoustic axis, and split-beam angle sensitivity are necessary for accurate echo strength compensation.

Range compensation

Range compensation is the systematic amplification of the received signal to remove losses in echo strength and volume backscatter due to geometric spreading and absorption of acoustic waves during their propagation to and from the scatterers.

Linearity

Linearity describes the proportionality of output to input signals. Linearity of a scientific echo sounder is a critical requirement for quantitative fisheries surveys.

Dynamic range

Dynamic range is the ratio between the minimum and maximum detectable signal that can be processed linearly. A wide dynamic range is a critical requirement for fisheries measurements as it defines the minimum and maximum signal amplitudes that are quantitative.

Noise

Noise is always present. It is ambient in the broadest sense, being due to the background environment, including the acoustic system and platform, and in producing reverberation when insonified. Both passive (transmitter turned off) and active noise (transmitter turned on) should be measured under all operational conditions.

Primary Issues:

On-axis sensitivity as a time series

Jitter in TS

Greater variability was observed in EK60 Mark I 38-kHz target strength than in EK500 38-kHz target strength (Fig. 2; Jech et al., 2003a,b). The EK60 and EK500 were alternately pinged in tandem with the same 12^{o}, split-beam transducer, and insonified the same 60-mm-diameter copper calibration sphere.

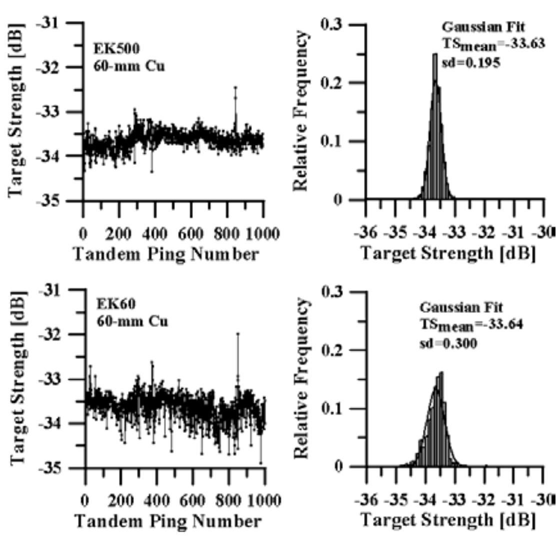

Figure 2. Time series and histograms of split-beam-determined target strength, as detected by Echoview, for a 60-mm-diameter copper sphere target near or on the axis. Ping rate was 1 ping s^{-1} per echo sounder and 1000 pings represent approximately 17

minutes. Mean split-beam target strength (TS) and standard deviation (sd) are derived from a Gaussian fit to the data. [Figure courtesy of M. Jech; Jech et al., 2003a,b]

Time scale of variability

Examination of the TS time series in Figure 2 indicates a ping-to-ping 'random' variability and a lower frequency oscillation. Ping-to-ping variability is expected, but the magnitude of the variability in the EK60 Mark I is greater than expected and greater than the EK500. The source of the lower frequency oscillation is unresolved.

Beam pattern

Echo strength compensation

Gaussian fits to near- or on-axis time series of EK500 38-kHz split-beam-determined target strength distributions revealed a normal distribution, while that from the EK60 Mark I was skewed (Fig. 2; Jech et al. 2003a,b). Split-beam-determined target strength was determined by Echoview using data exported from each echo sounder.

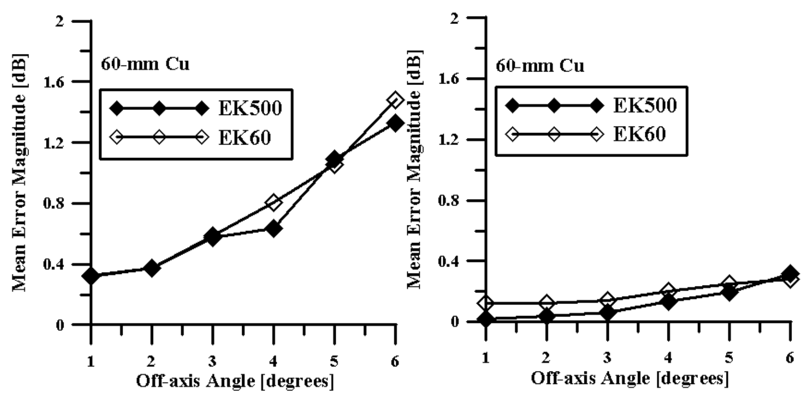

Figure 3. Mean of the absolute error, at 1° off-axis intervals, between target strength based on the experimental geometry and split-beam-determined target strength of a 60-mm-diameter copper sphere. Left panel: split-beam compensation as determined by the echo sounder without use of a measured angular offset. Right panel: split-beam compensation with use of a measured angular offset. [Figure courtesy of M. Jech; Jech et al., 2003a,b]

Potential axis alignment offset

The mean absolute error between target strength based on split-beam-determined angles and experimental-geometry-based angles of a 60-mm-diameter copper sphere increased with increasing off-axis angle (left panel, Fig. 3; Jech et al., 2003a,b). The error is reduced after including an offset in the measured angular target location. Near the acoustic axis, EK60 Mark I target strengths retained a small residual error (right panel, Fig. 3), whereas the residual error in EK500 target strengths was near zero (Jech et al., 2003a,b). These observations suggest a possible offset between transducer beam axis alignment and split-beam angle measurements.

Fewer target detections in EK60 Mark I

Significantly fewer single target detections were observed in the EK60 Mark I relative to the EK500 and to data processed using Echoview (Fig. 4). This observation indicates a significant change in single-target-detection algorithms between the EK500 and EK/ER60. In addition, the introduction of twice-Nyquist sampling in the EK/ER60 (Fig. 5) potentially requires users to modify single-target-detection criteria relative to the EK500; and criteria used with the EK500 may not be optimal for the EK/ER60.

EK/ER60 digital sample rate

The EK/ER60 ultimately samples the received signal at one-fourth the pulse duration (Fig. 5). Simulations using generated signals and noise demonstrate potential effects on TS and S_v measures (Fig. 6).

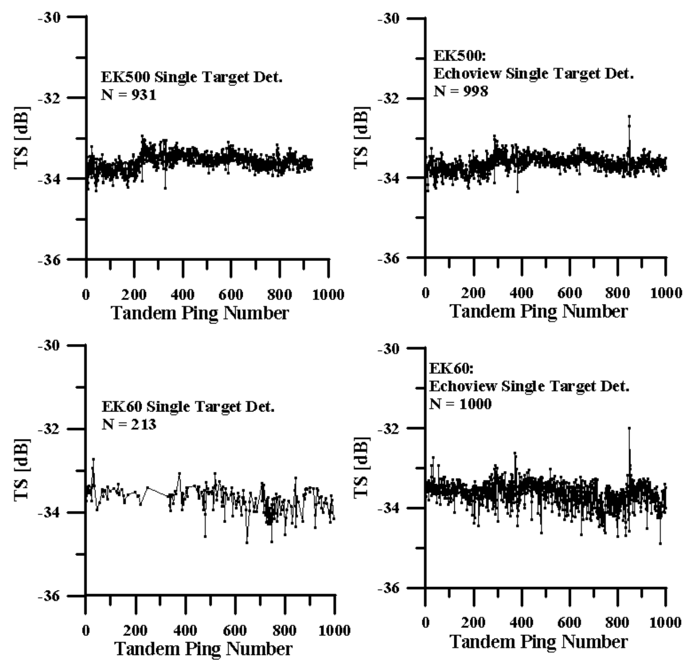

Figure 4. Time series of split-beam determined target strength, as detected by the EK500, EK60 Mark I, and Echoview, for a 60-mm-diameter copper sphere target near- or on-axis. See Fig. 2 for data description. [Figure courtesy of M. Jech; Jech et al. 2003a,b]

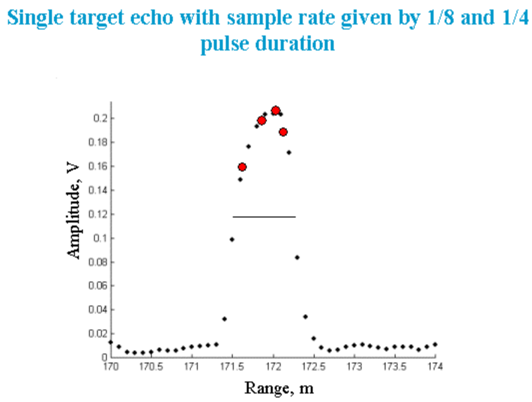

Figure 5. Digital representation of a single target echo from the EK500. Pulse duration is 1 ms (0.75 m) and sample rate is 7.5 kHz. The selected red dots indicate a sample rate of 3.75 kHz, just a little lower than the 4 kHz sample rate used by the EK/ER60. The Nyquist frequency corresponds to 1/2 pulse duration sample rate. [Figure courtesy of R. Kieser.]

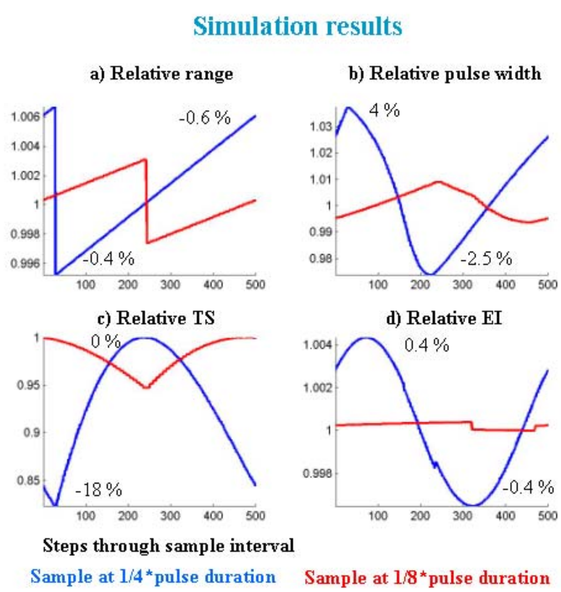

Figure 6. Relative range, pulse width, TS and EI as a function of sample point position. Sample point positions are incremented over one sample period. [Figure courtesy of R. Kieser.]

<u>Recommendations to EK/ER60 users</u>

- Examine other target strength time series.
  - Analyze target strength time series obtained from other 38-kHz EK/ER60 General Purpose Transceivers (GPT). Target strength time series should be collected with configurations similar to previously collected data, and by varying configurations, such as with or without a multiplexer, changing

transducer orientation, comparison to hull-mounted transducers, and modifying single target detection parameters.
- Analyze target strength time series from different frequencies using the same methods as above.
- The AFSC and John Horne indicated they have previously collected calibration data, and will analyze these data to determine if similar patterns are observed.

• Develop simulations to test EK/ER60 single target detection, echo strength compensation, and target strength methods (e.g., Fig. 7).

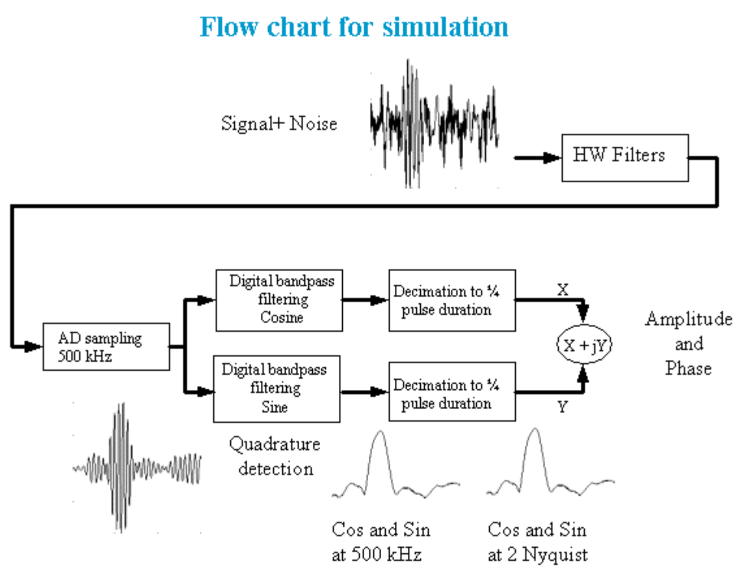

Figure 7. Flow chart to study the effect of sample rate on TS, pulse width, EI and other measurements. Typical signals highlight the process. [Figure courtesy of R. Kieser.]

• Conduct laboratory and *in situ* experiments to verify previous observations, and to test EK/ER60 echo strength compensation, beam pattern and beamwidth measurements, and target strength measurements.
- When conducting laboratory experiments, rotate the transducer between measurement trials to examine whether offsets between geometric and acoustic axes exist, and if so, are due to the mechanical mounting or rotation device or an offset between the transducer's acoustic axis and split-beam angle detection.

• Perform laboratory or "bench" tests using a generated signal.[1] Tests include:
- Measure split-beam transducer quadrant responses,
- Measure dynamic range,

[1] T. Ryan indicated CSIRO has designed and constructed a signal generator for input to an EK60 and is willing to share the design. K. Foote (WHOI) indicated the Institute for Marine Research (IMR, Bergen, Norway) developed a signal generator for the EK500 (Knudsen, 1985).

  - Evaluate linearity, and
  - Characterize noise.
- Evaluate the dynamic range of the EK/ER60 using a variety of targets that span a wide range of target strength. K. Foote suggested a 50-cm copper plate as an example of a target with large target strength. K. Foote indicated he has the recommended dimensions of the plate.

Recommendations to Simrad

- Document algorithms and implementation of:
  - single target detection,
  - echo strength compensation,
  - target strength measurement, and
  - digital sampling.
- Provide guidelines for proper selection of single-target-detection criteria for *in situ* target strength collection.
- Monitor the transmitter output power in real time and output these values as a data stream.
- Document the measurement of electrical phase and its conversion to mechanical angles and how phase deviation is calculated.

Recommendations to post-processing software developers

- Document algorithms and implementation of:
  - single target detection,
  - echo strength compensation, and
  - target strength measurements.

Secondary Issues:

Range compensation

Range compensation (time-varied gain (TVG)), which is a combination of spreading and absorption compensation, is a critical component of accurate target strength and volume backscatter measurements. Testing and evaluating range compensation algorithms implemented by Simrad was recognized as a need for the EK/ER60. Additionally, the attenuation parameter used by the EK/ER60 is limited in that it allows for input of only integer temperature and salinity values, which limits the precision with which absorption can be calculated and used.

Sound Speed

Sound speed is explicit in all acoustical measurements. It was recognized that sound speed is an often-overlooked parameter by the scientific community, echo sounder manufacturers, and 3rd party software developers. Sensitivity analyses on the effects of sound speed on acoustical measurements and descriptions of how sound speed are implemented in processing and post-processing algorithms are needed. Additionally, the EK/ER60 does not allow for a sound speed profile as did its predecessor, the EK500 (ROMS 5.30).

Development of calibration standards

As 38-kHz has been the standard frequency for marine echo sounders and surveys, calibration standards for this frequency have been developed, tested, and accepted. While Simrad develops and recommends standards for all of their systems, a need was recognized to test manufacturer recommendations and to develop standards for other operating frequencies.

Pulse repetition rate during calibration

Simrad recommends a ping repetition rate during calibrations of 1 ping per second, as was recommended with the EK500. Due to the significantly different architecture and realization of the EK/ER60, it is unclear whether this restriction is necessary.

Uninstalling transceivers for calibration

Simrad recommends uninstalling all transceivers other than the one being calibrated. John Horne has tested this and found no difference in calibration results when other transceivers were installed or uninstalled. It is unclear whether transceivers other than the transceiver being calibrated need to be uninstalled.

Sphere range greater than 10 m

Simrad recommended locating the calibration sphere at ranges greater than 10 m when calibrating the EK500. It is unclear whether this restriction remains necessary.

Beam pattern Harmonic Distortion

Distortion of beam patterns at frequencies greater than or equal to 120 kHz has been observed. This issue has been addressed and documented by Simrad (Tichy et al., 2003).

Number of single target detections

The EK500 was limited to 30 single target detections per ping. Clarification of whether this limitation still remains is needed.

Recommendations to EK/ER60 users

- Test range compensation in target strength and volume backscatter measurements. Tests should include independent evaluations of the accuracy of algorithms and implementation of time-varied gain in the EK/ER60.
  - Develop simulations to test and evaluate range compensation algorithms.
  - Conduct laboratory and *in situ* measurements to measure target strength as a function of range (r).
  - Evaluate range compensation as a function of pulse duration.
  - Conduct “bench” tests using externally generated signals.[1]
- Because the sample interval is dependent on the pulse duration, concerns over target strength dependence on pulse duration and digital sampling were expressed (e.g., Fig. 6). Target strength should be measured as a function of range (r),

where range variation (Δr) should be much smaller than the range that corresponds to 1 sample interval.

- Develop sensitivity analyses for affects of sound speed on target strength.
  - Evaluate implementing sound speed as a function of range (i.e., utilizing a sound speed profile).
- Initiate efforts to develop calibration standards for other frequencies (e.g., 18, 120, and 200 kHz).
  - Simrad supplies recommended standards for all their frequencies. These recommendations should be reviewed and examined.

<u>Recommendations to Simrad</u>

- Document algorithms and implementation of range compensation in target strength and volume backscatter data.
- Specify the 'receiver delay' for different pulse durations and other parameters if required.
- Document how sound speed is used in signal processing algorithms.
- Greater flexibility in use of sound speed.
  - Allow sound speed or salinity and temperature to be entered as a function of range (i.e., a sound-speed profile) in addition to a constant value.
  - Provide greater precision (i.e., tenths of units for temperature and salinity) in the selection of temperature and salinity values in the calculation of sound speed and absorption.
- Clarify whether the EK/ER60 requires limiting pulse repetition rate during calibration.
- Clarify the recommendation that transceivers, other than the transceiver being calibrated, must be uninstalled during calibration.
- Clarify the recommendation that the calibration sphere should be located at greater than 10 m range during EK/ER60 calibrations.
- Clarify single target detection algorithms and limitations.

<u>Recommendations to post-processing software developers</u>

- Document algorithms and implementation of range compensation in target strength data.
- Document how sound speed is used in signal processing algorithms.
- Request that sound speed or salinity and temperature be entered as a function of range.

LOBE Program:

The LOBE program was developed by Simrad to aid in echo sounder calibrations. The program has been upgraded from the DOS-based EK500 program to a windows-based program integrated into the EK/ER60 operation software.

s_A and/or S_v gain corrections are dealt with differently between the EK500 and EK/ER60, which has caused confusion in how to implement the s_A correction in the EK/ER60.

<u>Recommendations to EK/ER60 users</u>

- Evaluate the potential for using several targets at a single angular location to measure the beam pattern.
  - Currently the LOBE program accepts the first single target detection at an angular location and dismisses further detections at that location. Using several targets at a single location will provide estimates of variability as a function of off-axis location and may provide more robust estimates of the beam compensation. A recommendation for the scientific community and Simrad is to explore the benefits of using several echoes. M. Jech indicated he has data that can be analyzed for this purpose.
- Sensitivity analysis of LOBE program parameters (e.g., axis alignment offset, beamwidth).
  - LOBE output parameters are critical for calibrated data collection, however a sensitivity analysis has not been done to determine the severity of inaccurate parameter measurements on TS and S_v calculations. A recommendation is for the scientific community to conduct sensitivity analyses of LOBE parameters on TS and S_v results.

<u>Recommendations to Simrad</u>

- Document the s_A gain correction algorithm and how it is implemented through the LOBE program.

Survey-Related Issues:

Primary Issues:

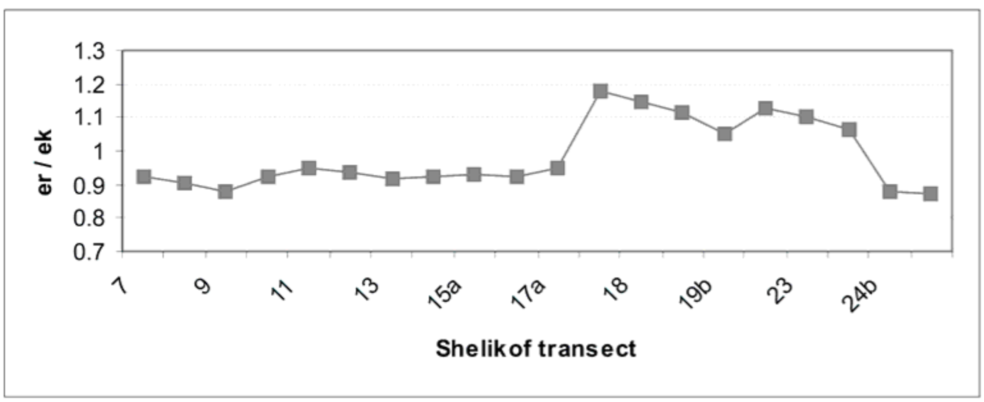

Figure 8. Ratio of mean s_A at 38 kHz from the EK500 (ROMS 5.30) and ER60 (V2.0.0) for transects conducted in Shelikof Strait. Note the dramatic increase in s_A ratio along transect 17 and dramatic decrease along transect 24. [Figure courtesy of N. Williamson]

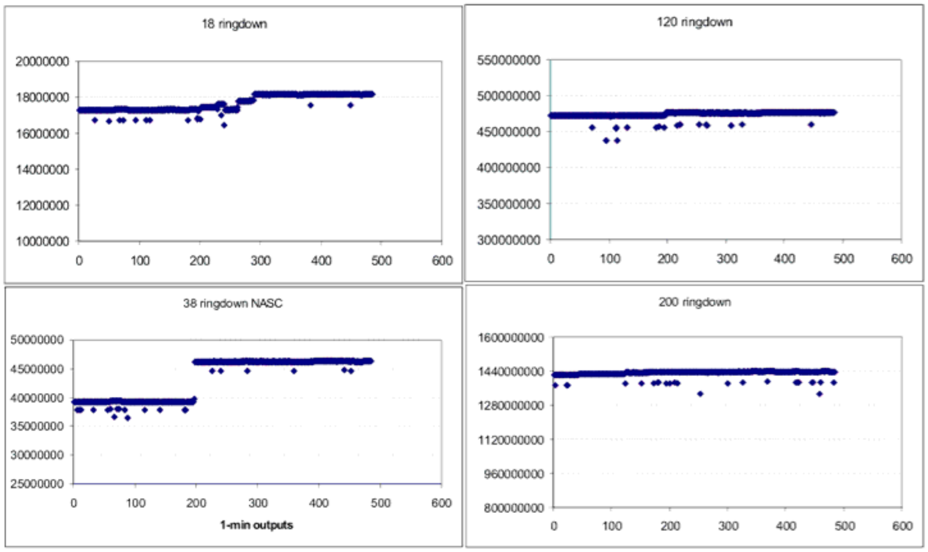

Figure 9. Ping-by-ping s_A values of the 'ringdown' portion of the received signal during transect 17 (see Fig. 8) from the ER60 (V2.0.0). Note the sudden increase in s_A in the 38-kHz ER60 s_A, which did NOT occur in the concurrently recorded signal from a 38-kHz EK500 (ROMS 5.30). [Figure courtesy of N. Williamson]

Erratic system performance

A 38-kHz EK500 (ROMS 5.30) and ER60 (V.2.0.0) were alternately pinged in tandem using a multiplexer device similar to that described in Jech et al. (2003) during a survey in Shelikof Strait in March 2004. The echo sounders shared the same 38-kHz, centerboard-mounted, split-beam transducer. Both sounders were calibrated and environmental parameters were set equivalently. During transect 17, a dramatic increase in the ratio of 38-kHz ER60 s_A to 38-kHz EK500 s_A was observed (Fig. 8). This increase occurred in both the 'Q' telegram and the raw data. During transect 24, a dramatic decrease was observed in the ER60 to EK500 ratio. Both jumps occurred rather suddenly. During transect 17, the sudden increase can be pinpointed to occur between two consecutive pings. There was no operator interference at this time. During transect 24, the reverse change occurred after the ER60 38-kHz GPT was uninstalled then reinstalled. Examination of the 'ringdown' portion of the echogram revealed a dramatic increase in ER60 38-kHz s_A, - coincident with the timing of the ER60 to EK500 s_A ratio jump in transect 17 (Fig. 9). Ringdown in the EK500 was stable for transects 17 and 24. For these analyses, 'ringdown' refers to the 1.0 m portion of the water column nearest the transducer face. Scrutinization of the bottom detections showed that these jumps were not due to intrusion of the seabed echo into the water column.

ER60 and EK500 38-kHz s_A differences

s_A values from the ER60 were10 to 20 percent different than s_A values from the EK500 (Fig. 8). The Elementary Sampling Distance Unit (ESDU) was 0.5 nmi and data were integrated throughout the water column for both echo sounders.

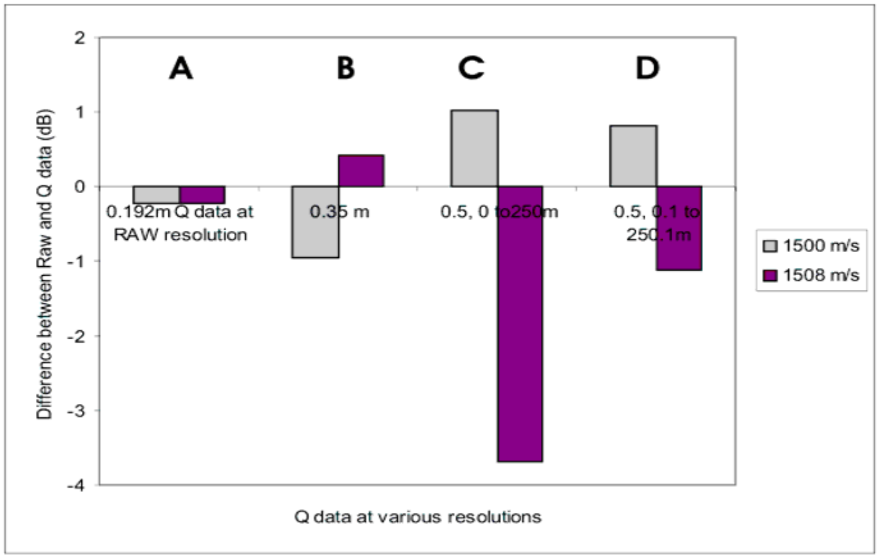

Figure 10. Discrepancies observed between 'Q-data' and 'Raw' data echo integration for identical portions of backscatter by a calibration sphere at 28 m depth at four vertical integration resolutions and 1500 m s^{-1} (blue) and 1508 m s^{-1} (red). A): Difference between 'Q-data' and integrated 'Raw' data at equivalent resolutions. Note discrepancy of 0.2 dB for both sound speeds. B): 'Q-data' resolution set to 0.35 m. C): 'Q-data' resolution set to 0.5 m and integrated over 0 to 250 m range. Note the large magnitude difference for the two sound speed settings and the signs of the difference. D): 'Q-data' have equivalent resolution as (C), but integration was offset by 0.1 m (i.e., integration over 0.1 to 250.1 m). [Figure courtesy of T. Ryan.]

Discrepancies between EK/ER60 'Q' and integrated raw data

EK/ER60 'Raw' data are the received signal digitized at twice the Nyquist rate (e.g., see 'EK/ER60 digital sample rate' above). 'Q-data' are the S_v values generated from the digitized signal via a Simrad resampling algorithm. 'Q-data' generation is user controlled and defined using the parameters: start depth, end depth, number of data points, and sound speed. Two sets of EK/ER60 data were obtained using two sound speed settings, 1500 and 1508 m s^{-1}, during a standard-target calibration. Large discrepancies were observed between results of echo integration of Simrad 'Q-data' and Simrad EK/ER60 'Raw' data, when the 'Raw' data were integrated to S_v values in Echoview (Fig. 10; Ryan and Kloser, 2004). Results of the comparisons showed that even very small changes in range resolution can have a dramatic effect on echo integration results (e.g., compare Fig. 10C with 10D).

Discrepancies occurred when converting 'Raw' data to 'Q-data' in the region of a calibration sphere echo (i.e., an echo with much greater magnitude than background). It is expected that the observed discrepancies will be near zero when randomly scattered echoes of similar magnitude are integrated. Therefore echo integration of either 'Raw' or 'Q-data' from typical field studies should give similar results, but this has not been tested.

The EK60 Mark I and ER60 algorithms use the 'Raw' data for calibration. Echo sounders that have been calibrated using the Simrad calibration program will not be affected by this problem. Errors would only occur if 'Q-data' were used for calibration purposes.

The discrepancies appear to be due to an error in Simrad's 'Raw' to 'Q-data' conversion algorithm. Simrad has advised that a fix for this will be included in their next release of the ER60 software (version 2.0.0 10.7.2003). Note that this error has been observed in ES60, EK60 Mark I and ER60 2.10 software. We also understand that EK500 has the same error but that the discrepancies between 'Raw' and 'Q-data' will be less than described here because of the higher sampling rate of the EK500. This has not been tested.

Recommendations to EK/ER60 Users

- Confirm these observations using other long-term time series collected with the EK/ER60.
  - N. Williamson indicated that AFSC will analyze other data collected on the FRV MILLER FREEMAN. M. Jech indicated he may have data to analyze.
- Conduct laboratory and 'bench' tests.
  - Operate the EK/ER60 echo sounder over time periods of days to weeks. J. Horne and N. Williamson indicated they plan to operate several EK/ER60 with the internal oscillator signal over time periods of days to weeks.
  - Test system stability using an externally generated signal.[1]
- Confirm observations by conducting *in situ* tests over days to weeks with other GPTs.
- Conduct laboratory and *in situ* tests with other GPTs and other frequencies.
- Monitor EK/ER60 performance regularly continuously during surveys. Potential diagnostics include:
  - Record the 'ringdown' s_A,
  - Monitor the transmit pulse on an oscilloscope,
  - Perform checks with the internal test oscillator, and
  - Collect passive noise data.
- Perform analyses to evaluate and compare S_v calculations in areas where scatterers are aggregated versus where scatterers are dispersed.
- Perform analyses to evaluate S_v calculations as a function of the integration bin size and initial start range, pulse duration, and sound speed. Example analyses are:
  - Offset the integration bin by Δr, where Δr is an integer multiple of the sample interval.
  - Generate S_v (i.e., 'Q-data') as a function of sound speed.

Recommendations to Simrad

- Comment on observed discrepancies between S_v values in the 'Q-data' and 'Raw' data.
- Document Simrad's measurement procedures for short and long-term instrument stability. State acceptable limits of stability for the EK/ER60.

- Document echo integration algorithms that are used in the processing software.
- Consider the creation of a text-based error log file that can be monitored by users in real time.

Recommendations to post-processing software developers

- Investigate and confirm observations of discrepancies between S_v values in the Q-telegram and S_v values calculated from power telegrams.

Secondary Issues:

Bottom detection

AFSC scientists observed a significantly higher frequency of faulty bottom detections with the EK60 (V.1.4.3.64) than the EK500 (ROMS 5.30). Simrad provided a fix with EK60 V.1.4.5.68 that corrected the original problem but introduced a 0.5 m offset. With the current version, V.2.0.0, both problems seem to have been resolved.

Metadata

It was recognized that system parameters, including the version number, are not easily accessible to users during post-processing or for analysis. Incorporating all system parameters and version numbers as metadata will significantly improve data analyses.

Vessel log

A discrepancy in the vessel log (cumulative nautical miles traveled) calculated by the EK500 (ROMS 5.30) and ER60 (V.2.0.0) has been observed by the AFSC. After approximately 12 hours of transecting, the EK500 had accumulated an additional 1.0 nmi relative to the ER60. The EK500 'Log' mode was set to "speed" with a GPGGA input navigation telegram. The ER60 "install-navigation" speed was set to auto and distance set to 'speed'.

Recommendations to EK/ER60 users

- Confirm efficacy of bottom detection algorithm in other data sets.
- Confirm vessel log discrepancy.

Recommendations to Simrad

- Provide system and operational processing parameters and the version number as metadata.
- Document bottom detection algorithms.
- Describe and document algorithm for vessel log calculations.

Recommendations to post-processing software developers

- Provide access to system and operational parameters and the version number to users during post-processing.
- Describe and document bottom detection algorithms.

DISSEMINATION OF INFORMATION

- The point-of-contact for SG-EK is the chair: Michael Jech (michael.jech@noaa.gov).
- The participants discussed using an e-mail 'listserver' for dissemination and communication among SG-EK participants, Simrad, post-processing software developers, and the EK60 user community. John Horne is currently setting up a listserver for the ICES WG-FAST and volunteered to set up a listserver for SG-EK. Subsequent to the workshop, M. Jech has investigated a 'discussion board', which is a web-based forum. M. Jech will investigate both options and create one on a trial basis.
- The participants discussed who should be included in the dissemination. The group concurred that the SG-EK members, Lars N. Andersen and Jeff Condiotty of Simrad, Ian Higgenbottom of SonarData, and the chair of WG-FAST should be included at this time. Further discussion is required to determine opening the list to the larger EK/ER60 user community.
- A letter has been sent to Olav Rune Godo of the Institute of Marine Research (IMR) in Bergen, Norway informing him of the workshop issues and inquiring as to IMR's experiences with the EK/ER60.

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