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Methods for Collecting and Using Backscatter Field Calibration Information for the Reson 7000 Series Multibeams

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Key words: Backscatter, Saturation, Reson.

SUMMARY

In support of Integrated Ocean and Coastal Mapping, the National Oceanic and Atmospheric Administration's (NOAA) Office of Coast Survey collects meaningful acoustic backscatter as a ancillary product of its navigational charting mission. Many of NOAA's field units have Reson 7000 series multibeam echosounders which have been shown to have decidedly non-linear response characteristics under certain high signal conditions. This non-linear behavior significantly increases the complexity of the radiometric corrections required to make use of backscatter under a variety of processing paradigms. Avoiding operating these systems in the non-linear operational domain is a simpler approach. However, the onset of non-linear behavior is not a simple function of the output signal level but instead depends on a number of tunable settings. Here we present a method for both determining the onset of non-linear behavior in any installed Reson 7000 series sonar and monitoring the system during real-time acquisition to ensure the system is operating in a linear fashion. In general this information improves the operator's understanding of the system status and can lead to additional post processing advantages.

1. INTRODUCTION

Office of Coast Survey (OCS), part of the National Oceanic and Atmospheric Administration (NOAA), is responsible for the maintenance of navigational charts within U.S. waters. OCS regularly conducts hydrographic surveys with the primary objective of updating navigational charts and products. In addition to the navigator, the information acquired during these surveys is valuable to a number of different communities: from fisheries ecologists studying habitat to offshore engineers siting wind turbines. In addition to high resolution bathymetry, these communities are increasingly requesting acoustic backscatter. Multibeam echosounders are one of the primary instruments OCS uses for bathymetric surveys and these sounders are also capable of collecting data that can be related to acoustic backscatter from the seabed. In the spirit of Integrated Ocean and Coastal Mapping, OCS has set out to provide reasonable quality backscatter to these other stakeholders.

One of the most common multibeams in use for NOAA hydrographic surveys is the Reson 7125.

These systems are capable of collecting backscatter in the form of Reson snippets. Under certain high signal return environments it has been shown that it is possible to drive the receiver of the 7125 into a nonlinear or saturated state (Greenaway 2010). Once the receiver reaches a saturated state the incident signal on the receiver can no longer be determined accurately and the backscatter becomes of limited use. The onset of non-linear behavior cannot be determined simply from the system output, but depends in a complex fashion on the applied system gain. Thus sounder gain settings and signal travel times (for time varying gain) are factors in determining whether the system is approaching saturation. With the current tools, it is difficult for sonar operators to know when the system is operating in a saturated state, and thus monitor for quality backscatter collection.

It has been observed that operators often run the Reson 7125 with high source levels and gain to facilitate strong echoes for reliable bottom detections and to maximize swath width. Receiver saturation is not clearly correlated with poor bottom detection quality, so the tendency is to error on the side of saturation. To provide the sonar operator with a sense of the state of receiver saturation in order to balance backscatter collection with bottom detection quality a “Saturation Monitor” has been developed through a joint effort between OCS and the Center for Coastal and Ocean Mapping at the University of New Hampshire. This application runs on the Reson topside processing unit or on an acquisition computer connected via local network. It uses the standard Reson 7000 and 7006 data packets (Reson, 2011) to assess the saturation state of the sonar receiver. The real time information is compared with previously collected field calibration information and displayed to the sonar operator.

2. METHODS

2.1 Monitoring Saturation Concept

The Reson 7125 receiver output has a linear relationship with incident signal amplitude until it eventually reaches a nonlinear state. As the system becomes nonlinear, the output of the receiver rolls off, eventually becoming constant despite an increasing signal level at the face of the transducer. Greenaway (2010) suggested a field calibration using the sea floor which provides the gain-dependent receiver output amplitude above which the receiver is considered to be in a non-linear state. If the total gain (fixed gain plus varying gain) and backscatter magnitude are monitored they can be compared to the estimated point of nonlinearity.

The tool described here has two functions. The first is to provide a standard method for collecting and processing the data required for determining the nonlinear region for a particular system. The output of this provides a “saturation curve”, which can be used to assess the state of saturation of the received signal level. The second is to provide visual information to a sonar operator concerning the saturation state of their system either real time or in post processing.

2.2 Field Characterization

The purpose of the field characterization is to define the linear operating range of the sounder. The basic concept is to cycle the sounder though all power and gain settings while gathering backscatter from a static sea floor target. Once adjusted for the applied power and gain, the backscatter signal from an unchanging target should collapse to a single value. By identifying when the corrected backscatter is no longer consistent, the transition to non-linear behavior can be estimated.

To standardize the operation of the sounder during the field calibration, a script for cycling a Reson system through selected gain and source level combinations is included in the described tool. The script also controls the ping rate and pulse length, and zeros the absorption and spreading settings to disable to application of time varying gain. Reson 7000 (sonar settings), 7006 (bottom detection information) and 7008 (snippets) records are requested via UDP by the calibration script and logged in Reson s7k format. During the calibration procedure, power is initially reduced to a minimum and the system is allowed to come to a steady state. The power is then slowly increased to insure that the commanded power setting recorded in the calibration data properly reflects the actual transmitted power. Rapid decreases in the power setting have been observed to cause a lag between the actual and commanded settings. For a given power level the gain is stepped up to the maximum gain for each increasing power setting as demonstrated in figure 1. Fifteen pings are recorded for each power and gain combination to gain some statistical confidence.

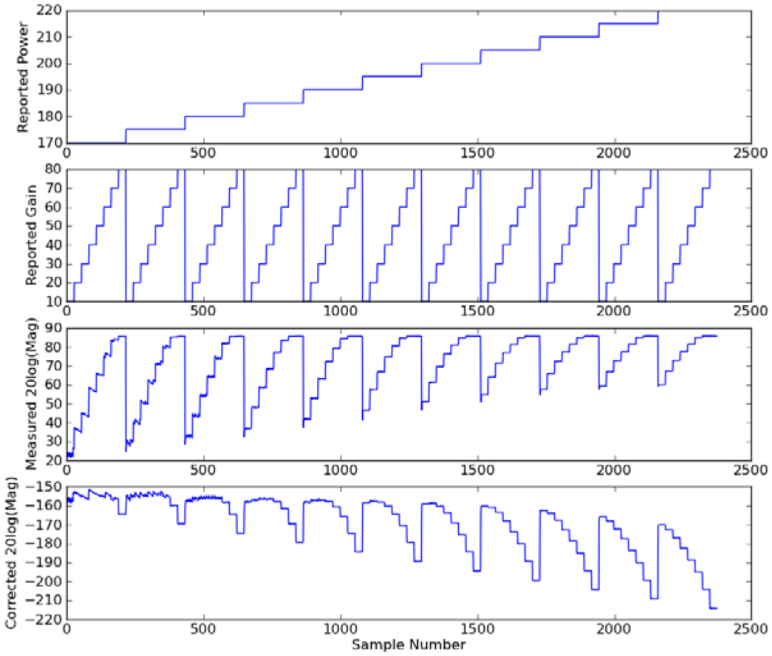

Figure 1 The transmit power and receiver gain settings, and backscatter, as cycled and collected by the described script.

Processing of this field calibration data has also been standardized. Since Reson snippets are dependent on valid bottom detections, and valid bottom detections may not always result from all power and gain combinations used, the true location of the sea floor needs be determined. Bottom detections for each beam are filtered by quality flags, accepting only the ”best” soundings. The soundings are then binned by range where the bin size is twice the pulse length. The bin with the largest count for each beam is assumed to be the range of the sea floor for that beam. All beams with the same range are grouped together in further processing.

For all pings with a given power and gain combination, the maximum received magnitude within the snippet record for each set of grouped beams is recorded. The maximum magnitude is used both because it is most likely to track the same point on the sea floor with any vessel motion, but also because the maximum value is what will first reflect nonlinearity. The recorded transmit power and receiver gain settings are assumed to reflect the actual power and gain used by the system. Reported backscatter increases linearly with power, but removing the applied power means the adjusted backscatter should remain the same over the power range. The same is true for gain. The recorded maximum backscatter is adjusted for the gain and power applied, and can be plotted for each range bin. The power vs backscatter adjusted for power and gain from a single range bin is shown in figure 2. Since the adjusted backscatter should not change with gain, all lines of differing gain should be collocated. Also, adjusted backscatter should not change with power so the adjusted backscatter should constant across power settings. Once the receiver becomes saturated, adjustments for commanded gain cease to represent the true gain applied by the system and the adjusted backscatter values appear to monotonically decrease.

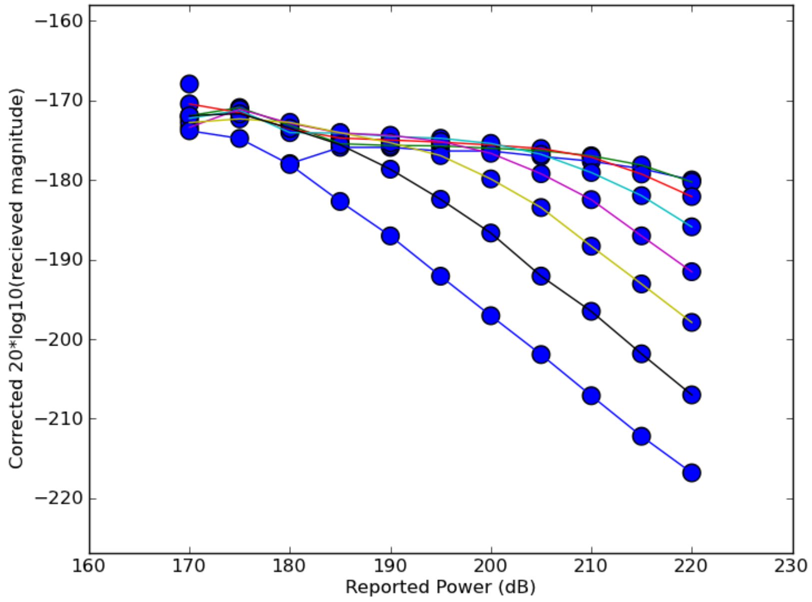

Figure 2 The corrected backscatter as a function of the power setting. Each line is a different gain setting.

Assessment of saturation for targets over different ranges is valuable because it allows for more flexibility in data collection conditions. Performing this test in shallow water over hard bottom means that close ranges may saturate for most gain settings, while larger ranges allow for the saturation point for more gain settings to be obtained. Only selected range bins are used by the script as currently implemented to reduce redundant processing.

For the current implementation user interaction is required to pick the points where saturation is occurring. It is desirable to reduce user interaction to make this process as quantitative as possible, and work continues to accomplish this goal. Once the saturation points are picked the saturation curve as a function of receiver gain and reported magnitude is defined. The curve for a particular Reson 7125 is demonstrated in figure 3.

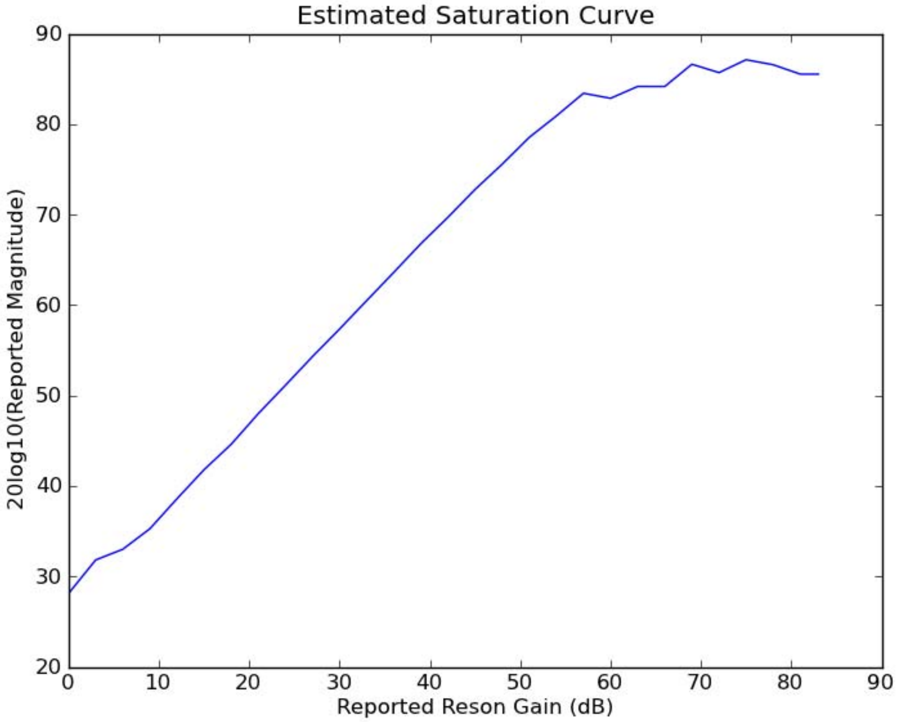

Figure 3 The saturation curve as estimated using the suggested field calibration approach.

2.3 Field Monitoring

Monitoring the saturation of the receiver is accomplished by comparing the reported magnitude to the saturation curve. This comparison is displayed visually either in real time or on a recorded file to determine the receiver's saturation state. Monitoring real time can help avoid saturating the receiver for extended periods while balancing settings for optimal bottom detection quality as normally determined on the Reson display. With older 8k systems the display brightness was not adjustable and the “glow” of the bottom signal served as a proxy for receiver level. With the new fully adjustable displays, the display brightness is not as useful. Watching the data replay on a file in post processing can help troubleshoot artifacts in backscatter products and could also inform backscatter processing algorithms on which should be omitted from seafloor characterization analyses.

Comparison of the recorded magnitude to the saturation curve requires that the total applied gain is accurately determined. This information can be extracted from the Reson 7000 and 7006 records which can be requested over the network and processed real time or extracted from a file. The applied time varying gain is determined from absorption, spreading and travel time, and then is combined with the fixed gain setting. The total gain vs received magnitude for each beam can be plotted with the saturation curve for a visual comparison as shown in figure 4. In this case the system is applying between 20 and 45 dB of gain and no beams are saturated as they are below the red line.

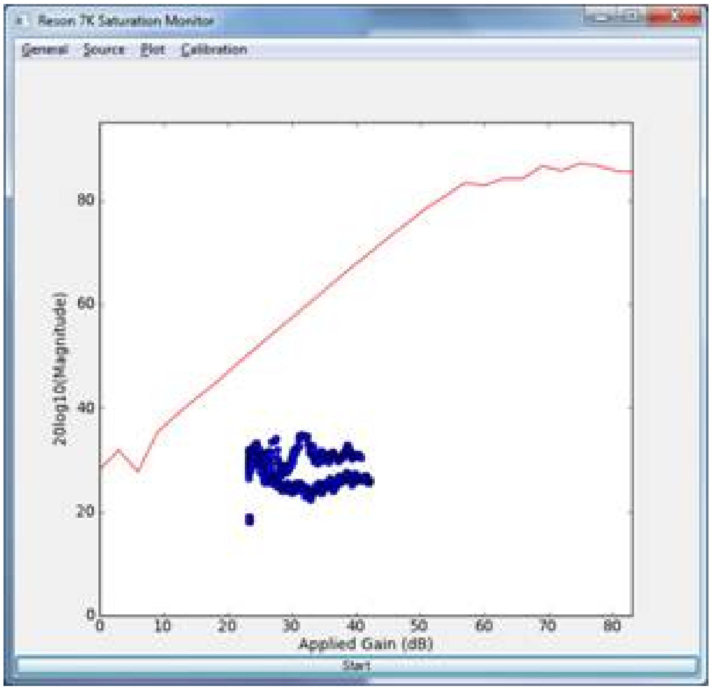

Figure 4 The saturation curve (red line) with the recieved magnitude for each beam (blue dots).

Another useful, and possible preferable, visualization is to normalize the received magnitude by the saturation value. A saturation value is extracted for each beam according the total applied gain and the saturation curve. The resulting plot is beam vs relative saturation, where the y axis is dB below the saturation value. The value in this type of visualization is that saturation can be correlated spatially with the swath giving a sonar operator the best information for comparison with other displays. Changing the power should result in a corresponding change along the vertical axis, and adjusting the absorption and spreading should have observable effects on the outer beams relative to nadir. Figure 5 demonstrates this kind of display for a sounder in an unsaturated state as all beams are below the red line. Assuming good bottom detections for all beams, the sonar operator can be relatively confident in reasonable operation of the system for both bathymetry and backscatter data collection.

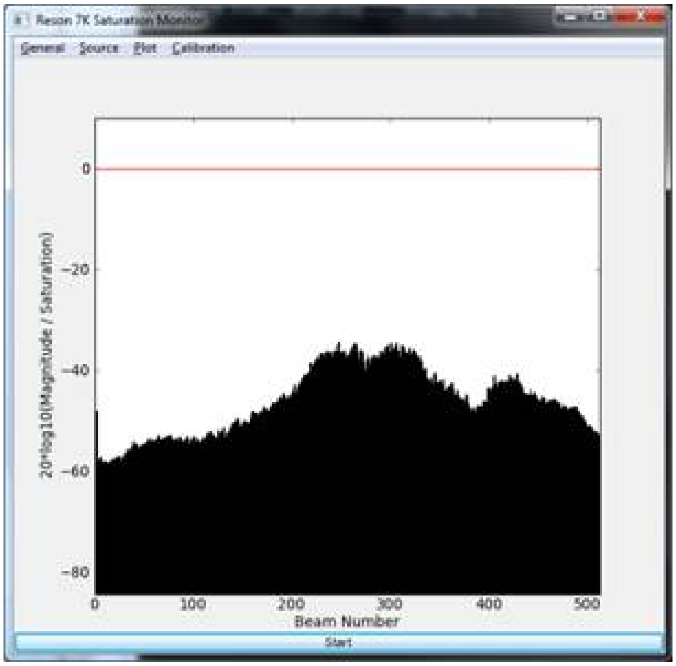

Figure 5 The received magnitude normalized by the saturation estiamte for each beam.

3. RESULTS

The described tool for monitoring saturation in the Reson 7000 series multibeam has been trialed on a single NOAA launch Reson 7125 and a Reson 7111 while the ship was alongside. While there is not quantitative evidence to show that this tool prevents or reduces backscatter saturation, trials are ongoing. Given the lack of information provided to a sonar operator regarding saturation, it would seem this information is better than none.

4. DISCUSSION

The saturation monitor evaluates real time information relative to a predefined saturation curve and displays this information to the sonar operator. This information can help the operator collect higher quality backscatter by avoiding receiver saturation. There are a number of additional considerations regarding backscatter collection with the Reson 7000 series sonar and the saturation monitor.

Regarding improvements for the saturation monitor, saturation curve extraction remains a weak point in the process. User interaction can be subjective and inconsistent, and this part of the code should be automated. In a few cases, particular field systems have produced odd results that would have made it difficult to automatically extract the saturation curve. Because the described calibration assumes the projector is operating as reported, nonlinearities in projector performance can make it difficult to extract the saturation curve in all cases. Even in the relatively stable case shown in figure 2 there appears to be a 5dB decrease across the power setting range. Eventually individual field calibrations for each system may not be necessary. It may be that a single saturation curve for all systems of a particular model is sufficient and no less accurate than field derived information. A limited number of Reson 7125 systems have been tested in controlled test tank conditions to extract this information. Further work should improve our understanding of the variability of these particular systems.

As with the applied power, it is important that the gain is reported correctly, since the saturation curve is dependent on the applied gain. With current 7125 systems there is an additional complication of determining the time varying gain since there is a discrepancy between the actual applied time varying gain and the equation provided in the operator's manual. The algorithms to compute the TVG as applied can be obtained from Reson and is vital to any backscatter work. It is possible that many artifacts in Reson 7000 series backscatter products are the result of poor knowledge of the true TVG curve.

Also important to the proper operation of the saturation monitor is the version of the Reson firmware. Versions previous to Feature Pack 1.3 do not correctly report the bottom detection magnitude in the Reson 7006 record, so snippet records must be used to obtain a bottom detection magnitude. Using snippet records for this purpose can significantly bog down the program, so Feature Pack 1.3 and later should be used so the smaller 7006 record can be used for this purpose.

Understanding the saturation point for the receiver is only part of the information needed by the operator. Ideally this would form the upper bounds for the plot described, and the lower bounds would be formed by the noise floor of the system. This could be extracted from the water column packet, but this record is somewhat bulky to handle over the network. With these upper and lower bounds, however, some of the guess work in proper operation of these sounders could be removed.

5. CONCLUSION

Backscatter collection with the Reson 7000 series sonar can be augmented with a real time monitor to avoid saturating the receiver. This is useful for sonar operators, even if not absolutely accurate, because no other monitoring mechanism is available. The saturation monitor tool described here provides the means to do a field calibration for the saturation curve. Future work should demonstrate whether a single curve for all systems of a particular model is more accurate than a field derived curve on a system by system basis.

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BIOGRAPHICAL NOTES

LTJG Glen Rice is a NOAA CORPS officer, currently stationed at NOAA's Integrated Ocean and Coastal Mapping Center. He has surveyed with NOAA along the coast of Alaska, in Chesapeake Bay, Gulf of Mexico, and in the U.S. Virgin Islands. His graduate work focused on Open Ocean Aquaculture Engineering while at the University of New Hampshire.

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