Calibrating a 90-kHz multibeam sonar

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Abstract- **Quantitative use of multibeam sonar requires calibration. Protocols for calibrating multibeam sonar in an absolute sense by means of a standard target are being developed. These protocols are illustrated for the Simrad SM2000 Multibeam Echo Sounder, with 90-kHz operating frequency and 300 beams over a 90-deg sector (±45 deg), each of nominal beamwidth 1.5x1.5 deg. In a sea well on Iselin Dock at the Woods Hole Oceanographic Institution, directional characteristics of the sonar were measured at the farfield range of 23 m in a sea well. At the large freshwater indoor tank at the University of New Hampshire, similar characteristics of directivity were measured at the nearfield range of 11.7 m. Beamforming was accomplished by digital signal processing. Beam patterns are presented and compared at both ranges. In addition, measurements of the on-axis response were made for each available time-varied-gain function, enabling linearity and dynamic range to be assessed.**

I. INTRODUCTION

A number of commercial multibeam sonars provide the water-column signal. In order to make use of this in quantitative applications, such as measurement of the numerical density of fish aggregations, calibration is essential [1]-[3].

In this paper, methods of measuring beam pattern, which have been developed for a sea-well acoustic calibration facility at the Woods Hole Oceanographic Institution (WHOI) and for a large indoor freshwater tank at the University of New Hampshire (UNH) Chase Ocean Engineering Laboratory, are outlined. These are based on backscatter from standard targets. Results are presented for the Simrad[**] SM2000/90-kHz Multibeam Echo Sounder.

II. METHODS

The subject sonar is the Simrad SM2000 multibeam sonar with 90-kHz operating frequency. This was used in its echo sounding mode, hence with an external transmitter positioned below and orthogonal to the receiving array. The elements of the receiving array are also used to transmit a signal in the imaging mode, but not in the present echo sounding mode. The transmitter is composed of a linear array of nominal length 86 cm. The receiving array is composed of 80 rectangular elements evenly spaced along a circular arc of radius 38.7 cm and spanning a total arc of 94.8 deg as measured between the centers of the end elements. By means of the external transmitter, the nominal beamwidth of each array is 1.5x1.5 deg. The real time display associated with the sonar shows 128 beams, admittedly with strong beam-to-beam dependences.

The transmitting and receiving arrays were mounted on a specially stiffened plate, which was bolted to a flange attached to a rotator shaft. At the WHOI sea-well calibration facility, the aluminum shaft was guided by a 6-m-long steel-trussed tower and supported by the rotation apparatus itself. The rotator was adapted from an antenna built by M2-Antenna Systems, Inc., as earlier described [4]. At the UNH freshwater-tank facility, the carbon-fiber shaft was supported by a computer-numerically-controlled (CNC) turntable, with shaft guided by a hinged member. At both calibration facilities, the nominal depth to the center of the transducer arrays was about 3 m.

A number of standard targets were used, as described in a companion paper [5].

The nominal nearfield-farfield transition distance for the sonar is about 22.5 m. At the WHOI facility, the principal measurements were made at a range of 23 m. At the UNH facility, the measurements were made at a range of 11.7 m. Thus the two ranges straddle the transition distance within which nearfield effects may be expected to apply. In both cases, the transmit array was shimmed so that the acoustic axes of the transmit and receive arrays intersected at the standard-target range.

Transmission of the echo sounder was controlled at the rate of one ping per 2-s interval. Operating parameters of the system as used at the two facilities are presented in Table 1.

The transducer arrays were rotated about the vertical axis of the supporting shaft by means of the respective precision turntables at the two facilities. This was controlled by a personal computer (PC). Rotation data were logged with the calibration sonar data, but with a time lag of 5 pings.

[**] Any use of trade names does not imply endorsement by NOAA

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14. ABSTRACT

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Table 1. Relevant operation parameters of Simrad SM2000/90 kHz used in the experiments.

	Sea Well (WHOI)	**Indoor Tank (UNH)**
Pulse Duration (μs)	300.8	300.8
Sampling Rate (kHz)	48.485	48.485
TVG (dB)	40 log(r)	20 log (r)
Transmit Power Setting	High	low
Repetition Rate (pings/sec.)	0.5	0.64

Before measuring the main lobe of the beam pattern, the beam pattern in a vertical plane was measured. This was done by recording 10-30 pings from the standard target in a fixed position, then raising the target by a constant interval corresponding to about 0.2 deg, for example. This operation was repeated to fully span the upper part of the main lobe of the beam pattern. Similar operations were performed for the lower half of the main lobe. The data were plotted and the position of greatest sensitivity determined. This position was regarded as the central acoustic axis of the array.

The beam pattern measurements were performed with respect to this reference. The beam pattern was measured in different horizontal planes by sweeping the array past the target, then repeating the operation for the sphere at a raised or lowered position. The signals from all 80 elements, or channels, were recorded at each angular position.

At WHOI, the farfield measurements were made with a time-varied-gain (TVG) function of 40 log *r*, where *r* is the range. At UNH, the nearfield measurements were made with a TVG of 20 log *r*, which was determined as the optimal TVG by comparison with the other system-available TVG functions.

Following each trial, the raw echo time series from the 80 elements were reduced to beams by digital signal processing on a PC. Each of two functions was plotted: the azimuthal response in the central, horizontal plane, and the beam pattern as measured over an area normal to the central acoustic axis and spanning the main lobe. Additional dependences were plotted.

Because the UNH measurements were performed in the nearfield, the on-axis region was numerically computed according to an analytical model.

III. RESULTS AND DISCUSSION

Farfield measurements

These measurements were made in a sea well on Iselin Dock in Woods Hole in May 2003. Measurements of the beam pattern in a vertical plane are shown in Fig. 1. Both the averaged and maximum values for the nominal ten echo time series at each target depth are plotted. As a consequence of this measurement, the nominal central target depth, in the arbitrary units of the measurement, was chosen to be 50 cm.

The beam pattern in the central azimuthal plane is shown in Fig. 2. A total range of jitter in the beam pattern measurement in the central azimuthal plane is observed to be 1 dB.

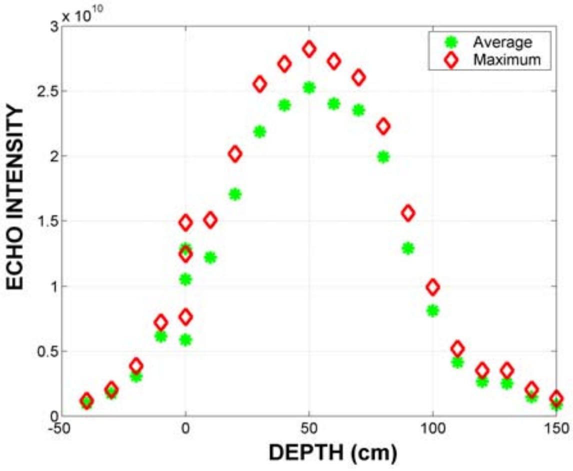

Figure 1. Vertical beam pattern measured at 23 m in the sea well on Iselin Dock in Woods Hole.

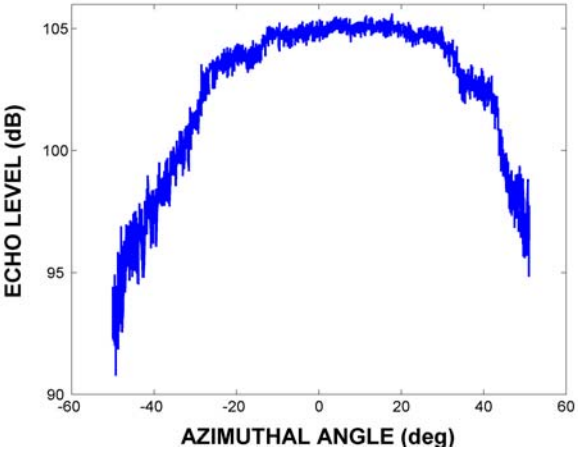

Figure 2. Horizontal beam pattern measured in the central azimuthal plane at 23 m in the sea well on Iselin Dock in Woods Hole.

The beam pattern over the main lobe is shown in Fig. 3. This shows a similar consistency over the central 40-50 deg sector. The isolines are separated by 1 dB, indicating a central beamwidth of about 2.0 deg for the central 90-deg sector. This is somewhat broader than the nominal beamwidth of 1.5 deg.

Nearfield measurements

These measurements were made in the freshwater tank at UNH in June 2003. Several measurements of vertical beam patterns were made. One with very high resolution is shown in Fig. 4, indicating a relative depth that is very close to the nominal central position of 0 m in relative units. At the central position, the on-axis response was measured for the range of available TVG functions, plotted in Fig. 5. On the basis of this, the 20 log *r* TVG function was selected for display and logging of the data.

The azimuthal dependence of the beam pattern in the central plane is shown in Fig. 6 and that for the main lobe in Fig. 7. The small jitter in Fig. 6 is about 0.2 dB.

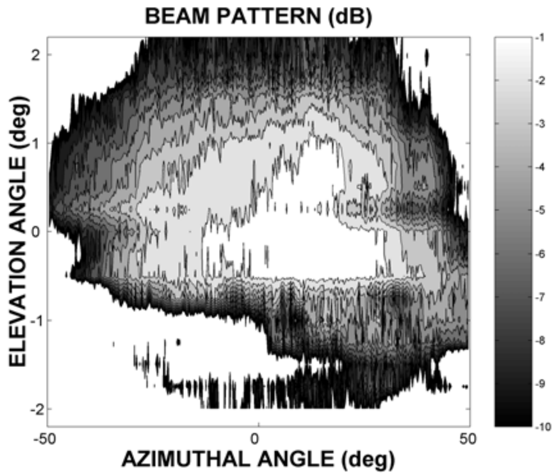

Figure 3. Two-dimensional beam pattern of SM2000/90 kHz measured at 23 m in the sea well on Iselin Dock in Woods Hole.

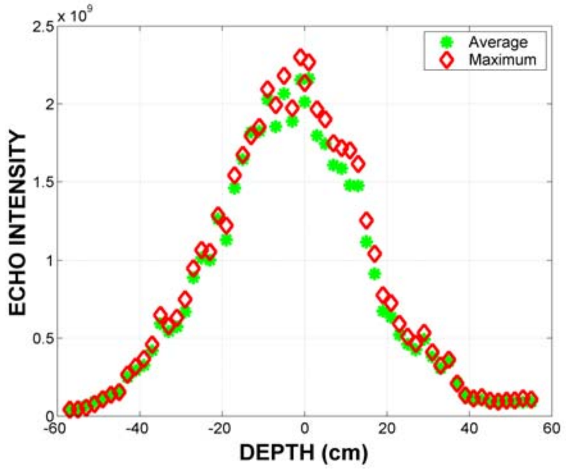

Figure 4. Vertical beam pattern measured at 11.7 m in the freshwater tank at UNH.

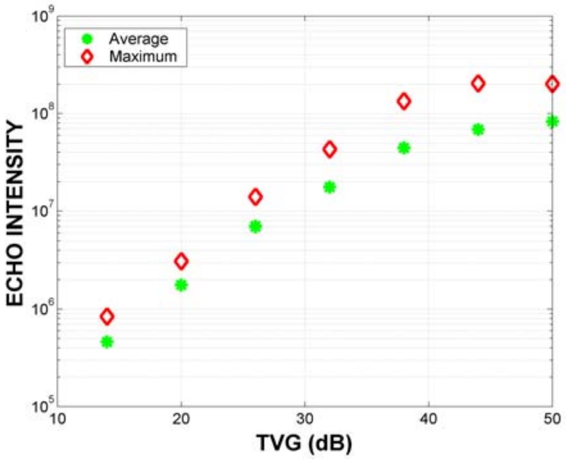

Figure 5. TVG measurement in the freshwater tank at UNH.

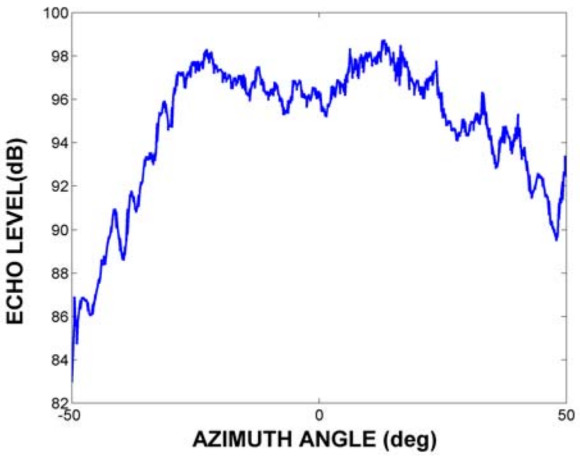

Figure 6. Horizontal beam pattern measured at 11.7 m in the freshwater tank at UNH.

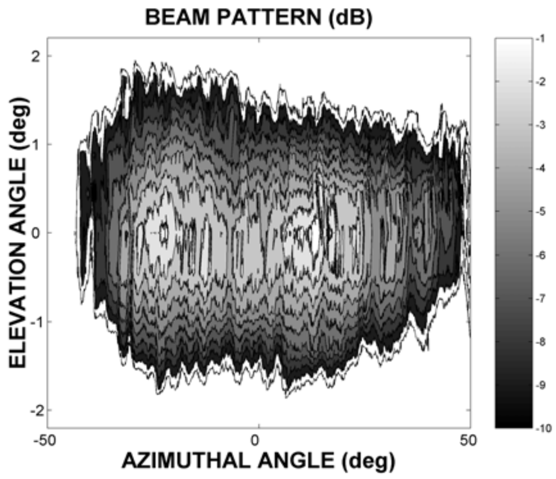

Figure 7. Two-dimensional beam pattern of SM2000/90 kHz measured at 11.7 m in the freshwater tank at UNH.

Comparison of farfield and nearfield measurements

The corresponding measurements of vertical beam pattern at 23- and 11.7-m ranges reveal a similar central beamwidth of order 1.3 deg. This is somewhat narrower than the nominal beamwidth of 1.5 deg

Measurements of the beam pattern in the central azimuthal plane, Figs. 2 and 6, reveal different degrees of jitter. Those made at the UNH facility are cleaner. The UNH nearfield measurements also show more structure, but are made within the nearfield distance, where the beam is not yet fully formed.

The main lobe of the beam pattern is consistent for the measurements at the two ranges. More structure is evident with the nearfield measurements, but in the case of the vertical beam pattern, Figs. 1 and 4, the central beamwidths are roughly similar.

In order to assess the influence of the nearfield, the on-axis sensitivity of the multibeam sonar was measured at the UNH facility. This was done by moving the transducer toward and away from the target, spanning target ranges over 3-14 m. The range dependence was also computed from an analytical expression. This is shown with the data themselves in Fig. 8.

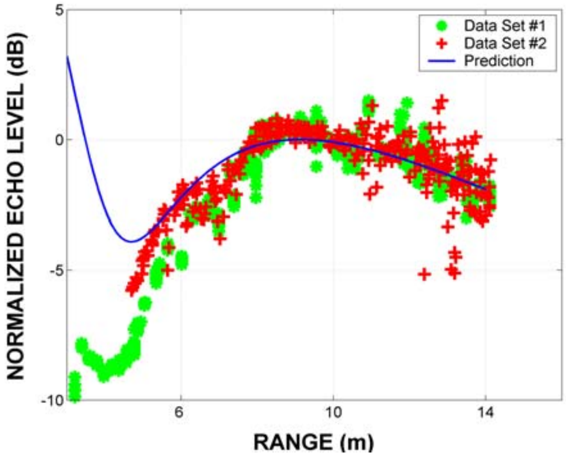

Figure 8. Influence of nearfield effect on the normalized echo level as a function of range along beam axis.

IV. CONCLUSIONS

Calibration measurements with the SM2000/90-kHz multibeam sonar in its echo sounding mode reveal an approximate consistency with the nominal system specification in terms of beamwidth. However, considerably more structure is revealed too, which is important for quantitative applications.

To realize quantitative use of the sonar, as for echo integration and target strength measurement [6], the sensitivity of the system must be quantified. The basic data have now been collected to do this.

Protocols continue to be developed for multibeam sonars used for water-column measurement. Earlier work has now been extended to include effects of TVG and measurement in the transducer nearfield.

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