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4pAO2. Testing of an extended target for use in high frequency sonar calibration
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Acoustic backscatter tests were performed in a tank with a 200-kHz, 7°, SIMRAD EK60 Single-Beam Echo-Sounder, and a 256-beam RESON SeaBat 7125 Multi-Beam Echo-sounder. Tests were done in order to investigate the angular and range dependency of the scattering strength of a new test target in order to validate its use in sonar testing. This target was constructed of small chain links arranged in a 'curtain' simulating an extended scattering surface, such as the seafloor. Target strength for individual links was collected as the links were rotated 360°. The links are combined into an extended surface target, spacing between scatterers being approximately 1 cm. The scattering network irregularity is enough to ensure phase randomicity at the wavelength considered. The target scattering strength was measured as a function of grazing angle and range, hence varying the number of scatterers within the beam footprint. These tests suggest that the amplitude envelope of the scattered signals is Rayleigh distributed and that the backscatter strength depends linearly on the number of active scatterers, all desirable features for calibrating sonars used to make measurements of similarly random surfaces such as the seafloor. Results show a promising in-tank calibration technique alternative to the classical sphere-target measurements.

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Introduction

Standard calibration Spheres are often used for calibrating single and split-beam echo sounders (SBES) as well as multibeam echo sounders (MBES) [Foote et al., 1987; Foote et al; 2005]. These spheres behave as discrete targets with backscatter characteristics that are independent of incident angles, and have a known target strength ($TS$) value depending on their size and material (often tungsten carbide or copper). The most commonly used standard calibration spheres are small compared in comparison to the beamwidth of most SBES and MBES, making them useful for estimating $TS$ but providing incomplete information when generating estimates of surface scattering strength ($Ss$). As an alternative, a planar target comprised of many known point scattering elements can be used to provide a calibration that can be used to directly test the accuracy with which SBES or MBES systems can estimate $Ss$, a quantity that is often desirable when, for example, characterizing seafloor habitat. A suspended jack-chain target (Fig.1) is likely suitable for this purpose and a prototype was built at UNH CCOM/JHC, but validation was required to check the relevance of this concept. This paper describes the acoustic characteristics and validation of the jack-chain target.

![Jack Chain “Curtain” Target](image1)

**FIGURE 1.** Jack Chain “Curtain” Target (left) and individual link (right).

Methodology

The Acoustics Engineering tank in the Chase Ocean Engineering laboratory at the University of New Hampshire was utilized to conduct the study.
A test of angle-dependent $TS$ for individual links was performed by assembling a simple rotary table fixture and measuring the return signal of a single link at several angles at a range of approximately 8.8 meters. This test, and all subsequent tests, was performed in an 18x12x6 m (length x width x depth) freshwater tank in the Chase Ocean Engineering laboratory at the University of New Hampshire. A calibrated SBES was set to ping at each target, one at a time, while the target was rotated a full 360° in 45° increments. To ensure adequate repeatability and to enhance statistical confidence, twenty five chain links were tested. An average $TS$ value for a single link was determined through this investigation.

The jack-chain target was then constructed by assembling approximately 200 two meter long chains into a curtain. This curtain was suspended in the water from a float in the test tank. The float was fixed flush to the back wall of the Engineering Tank, such that the chain target was suspended a distance of approximately 2 m in front of the wall, hanging vertically in the water, and was moved along the wall to change the angle of ensonification. The transducer assembly was held in a single fixed location and was rotated horizontally in 5° increments from $-50°$ to $50°$ incidence angle onto the target plane. The MBES was used to ensure that the SBES beam was steered at the center of the target.

Backscatter from the assembled jack-chain target was then collected with the same calibrated SBES at incidence angles between -50 to 50 degrees in order to examine the angle-dependence in the backscatter. In addition, the distance between the SBES and the jack-chain target was varied in order to test for a relationship with range at two fixed angles: normal incidence and 45°. Potential changes in backscatter statistics related to the number of chain-links in the SBES beam range-dependent footprint were of particular concern.

The $TS$ measurements made with the SBES during these tests can be regarded as the relative portion of the pulse intensity that is redirected back to the receiver. In the case of a surface extended target such as the jack-chain target investigated here, the $TS$ term is defined as follows.
\[ TS = S_s + 10 \log(A) \] (1)

where \( S_s \) is the Scattering Strength (in dB / 1 m²), and \( A \) is the ensonified area (m²). This makes clear that \( TS \) is the response of the ensonified target at a given instant (depending on the measurement configuration), while \( S_s \) is the reflectivity characteristic of a unit area, intrinsic to the target. Alternatively, \( TS \) can also be defined as follows.

\[ TS = 10 \log(\frac{I_s}{I_i}) \] (2)

Where \( I_s \) is the scattered intensity and \( I_i \) is the incident intensity. Using equation 1, the Scattering Strength \( S_s \) can be easily derived from the measured Target Strength \( TS \).

\[ S_s = TS - 10 \log(A) \] (3)

The area term \( A \), can be approximated at normal incidence as the primary beam footprint of the SBES:

\[ A = \pi (H \tan(\frac{\theta_{-3dB}}{2}))^2 \] (4)

where \( H \) is the distance from the target (m) and \( \theta \) is the beam angle aperture defined at -3 dB, nominally 7° for the SBES that was used throughout this study [Lurton, 2010]. SBES measurements of both \( TS \) and \( S_s \) (using Eq. 3) were collected for all tests.

**Results**

An average Target Strength value was determined for individual links. Regardless of orientation, it was found to be -55 dB. This value was found by averaging all the ratios of scattered intensity to incident intensity values from every angle of the 25 tested links.

The measurement of the angular dependence of the individual link response showed no significant trend (Fig. 4). No well-defined pattern between rotated angle and \( TS \) is evident from link to link, while the measured values remain concentrated in quite a narrow dynamic range (-59 to –53 dB).

![Figure 4. Individual Link Response Examples](image-url)

Figure 5 shows individual observations (i.e., single pings) of \( TS \) and \( S_s \) data collected as a function of incident angle measured at a normal range of 7 meters. \( TS \) values show angle dependence with higher \( TS \) near normal incidence and lower \( TS \) at oblique incidence, approximately tracking the beam footprint size changes with...
incidence angle. Average $S_s$ values show weak or no angle-dependence. An average value of the four trials at each angle is included. The $S_s$ data has also been condensed (independently of angle) and used to estimate the probability density function (pdf) of the equivalent amplitude value ($10^{S_s/20}$). This pdf is compared with a Rayleigh distribution in figure 6.

![Figure 5](image-url)  
**FIGURE 5.** Target Strength (left) and Scattering Strength (right) as a function of incident angle.

![Figure 6](image-url)  
**FIGURE 6.** Comparison of the scattered amplitude distribution (blue histogram) with a Rayleigh distribution (red curve)

Finally the range dependence of the Target Strength and the Scattering Strength was investigated. Fig.7 depicts this dependence for ranges varying from 1 to 6 m.
Discussion

The 25 individual links that were tested produced an average $TS$ value of -55 dB. This value was attained by averaging all the ratios of scattered intensity to incident intensity values from every angle of the 25 tested links. The results displayed in figure 4 do not show a significant (or repeatable) relationship between incident angle and the resulting $TS$.

The $SS$ results from the jack-chain target showed little dependence between the angles of incidence and the $SS$ values, suggesting that the target $SS$ is independent of the angle of incidence. It is worthwhile to note a comparison of the average measured $SS$ and the individual link $TS$. The average measured $SS$ is about -12 dB/m² and the average individual link $TS$ is about -55 dB. The difference between the two figures is the number of links per square meter. The typical number density of the chain is 1/cm², thus there are about $10^4$ links per square meter. The difference is $10\log(10^4) = 40$ dB. This conforms well to the 43 dB difference between -12 dB and -55 dB. Despite the relatively low number of samples used in this comparison, the agreement is quite satisfactory, and confirms that the hypothesis for a Rayleigh regime is indeed correctly fulfilled with this target configuration, as seen in figure 6.

The Target Strength values increase with range, which is expected due to the dependence of the target extent. The Scattering Strength obtained after compensation of the ensonified area shows a behavior independent of the measurement range, confirming that the measurement configuration is correctly compensated for.

The efforts summarized here are to support the claim that this prototype target is suitable for echosounder calibration. The tests that were conducted show that the amplitude envelope of the scattered signals is Rayleigh distributed and that the backscatter strength depends on the number of active scattering elements. These are desirable features for calibrating echosounders used to make measurements of similarly random surfaces like the seafloor. Further experimentation would be justified and worthwhile at this point to determine the extent of this targets capabilities.

FIGURE 7. Target Strength (left) and Scattering Strength (right) as a function of range, at normal incidence (top) and oblique 45° incidence (bottom)
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References


