RECOMMENDATION FOR SOUND SOURCE LEVEL AND PROPAGATION ANALYSIS FOR HIGH RESOLUTION GEOPHYSICAL (HRG) SOURCES

Why we have concerns with using many of the currently available sound source verification (SSV) measurements for HRG sources?

When NMFS compared the numerous field SSV measurements for HRG sources with the source levels measured in a controlled experimental setting (i.e., Crocker and Fratantonio, 2016), we found significant discrepancies in isopleth distances for the same equipment that cannot be explained solely by absorption and scattering of acoustic energy. The field SSVs generally point to much lower source levels and yield much smaller impact zones when compared to measurements provided by Crocker and Frantantonio using a traditional geometrical spreading loss model. In addition, we also noticed discrepancies exist among different SSV measurements by different companies for the same equipment, which also cannot be explained and raises further concerns about the reasons for the variability. We suspect that these large discrepancies may be due to difficulty and inconsistency in the field in terms of adequate on-axis measurement of the signal for these HRG sources, i.e., many field SSVs were likely measured outside the main lobe of the source at various degrees (and the reports do not contain any information to confirm otherwise).

Recommendations on source levels and propagation modeling

While we are in the process (including working with BOEM) of better understanding existing sound measurements and determining the best methodologies to recommend to ensure that future sound measurements can be confidently used to estimate an ensonified area, we recommend the method below for determining the root-mean-square sound pressure level (SPL_{rms}) at 160-dB isopleth for the purposes of estimating Level B harassment take. This method will allow us to use source levels with less associated uncertainty (as compared to the SSVs referenced above), while also incorporating frequency, water depth, and some directionality to refine the estimated ensonified zones.

First, we recommend using the source levels provided by Crocker and Fratantonio (2016), In cases when the source level for a specific HRG source is not provided in Crocker and Fratantonio (2016), the source level provided by the manufacture should be used.

If only peak source sound pressure level (SPL_{pk}) is given, the SPL_{rms} can be roughly approximated by subtracting a certain amount of decibels from the reported SPL_{pk} values to derive the corresponding SPL_{rms} values for different source types (Table I, S. Labak, pers. comm., 16 August 2019).

Table I. Amount of decibels subtraction from known SPL_{pk} to approximate the corresponding SPL_{rms} source levels for different types of HRG sources.

Source Type	Difference between SPL_{pk} and SPL_{rms} (dB)
Ideal tone*	3 dB
Boomer	7 dB
Single frequency/FM sonar	6 dB
Sparker	7 dB
GI airgun	6 dB
Bubblegun	6 dB

* Shown as comparison to actual HRG sources listed below.

Accounting for Absorption

In order to account for the greater absorption of higher frequency sources, we recommend applying 20 log(r) with an absorption term $\alpha \cdot r/1000$ to calculate transmission loss (*TL*), as described in Eqs. (1) and (2) below.

$$TL = 20\log_{10}(r) + \alpha \cdot r/1000 \text{ (dB)} \tag{1}$$

where r is the distance in meters, and α is absorption coefficient in dB/km.

While the calculation of absorption coefficient varies with frequency, temperature, salinity, and pH, the largest factor driving the absorption coefficient is frequency. A simple formula to approximate the absorption coefficient (neglecting temperature, salinity, and pH) is suggested by Dr. Michael Ainsile (per. comm., 13 September 2019):

$$\alpha \approx 0.000339 f^2 + 48.5\frac{f^2}{f^2+5715.36} \text{ (dB/km)} \tag{2}$$

where f is frequency in kHz. This formula is a simplified version of the equation for calculating sound attenuation coefficient provided in Ainsile (2010, p.29) that omits the boric term, as it is negligible at the frequencies we are interested in.

Please note when a range of frequencies, is being used or is produced by a device, the lower bound of the range should be used for this calculation, unless there is certainty regarding the portion of time a higher frequency will be used, in which case the result can be calculated/parsed appropriately.

Accounting for Beamwidth

Further, if the beamwidth is less than 180° and the angle of beam axis in respect to sea surface is known, the horizontal impact distance can be calculated. Most, if not all, sparkers and boomers are omnidirectional sources, thus should use 180° as the beamwidth. In calculating the horizontal distance, it is also important to first know the water depth, especially where the survey is conducted in shallow waters.

The following describes the steps used to calculate the horizontal distance from an HRG source.

1. **Determine the vertical component *h* of the slant distance *r*.**

(1) If the beam direction is not directly downwards, but with an angle of beam axis respect to sea surface ϕ (as shown in Figure 1). The vertical component h can be calculated using

$$h = r \sin\left(\varphi - \frac{\theta}{2}\right) \text{ (m)} \qquad (3)$$

where θ is the beamwidth (in radian), and ϕ is the angle of beam axis in respect to sea surface (in radian).

(2) If the beam direction is pointed at a normal downward direction (as shown in Figure 2), Eq. (3) can be simplified as

$$h = r \sin\left(\frac{\pi}{2} - \frac{\theta}{2}\right) = r \cos\frac{\theta}{2} \text{ (m)} \qquad (4)$$

where θ is the beamwidth (in radian).

2. **Determine the horizontal distance *R* (Level B harassment distance)**

(1) If the beam direction is not directly downwards, but with an angle of beam axis respect to sea surface ϕ (such as the case in 1(1)), then use one of the following equations to calculate the horizontal distance R, depending on water depth d.

(a) If water depth d is greater than or equal to the vertical component of the slant distance h (i.e., $d \geq h$), then the horizontal distance is

$$R = \frac{h}{\tan\left(\varphi - \frac{\theta}{2}\right)} \text{ (m)} \qquad (5)$$

as shown in Figure 1(a)

(b) If the vertical component of the slant distance h is greater than water depth d (i.e., $h > d$), then the horizontal distance is

$$R = \frac{d}{\tan\left(\varphi - \frac{\theta}{2}\right)} \text{ (m)} \qquad (6)$$

as shown in Figure 1(b)

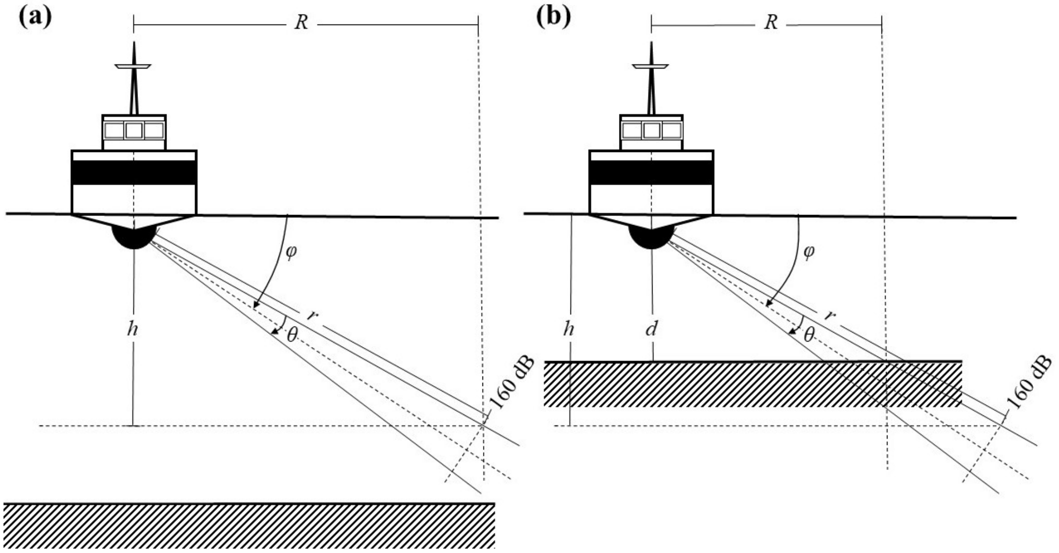

Figure 1. Schematic diagrams showing horizontal impact distance *R* in relation to acoustic beamwidth *θ* and beam angle *φ*. (a) Water depth *d* is greater than the vertical component of slant distance *h*, and (2) water depth *d* is less than the vertical component of slant distance *h*.

(2) If the beam direction is pointed at a normal downward direction (such as the case in 1(2)), then use one of the following equations to calculate the horizontal distance *R*, depending on water depth *d*.

(a) If water depth *d* is greater than or equal to the vertical component of the slant distance *h* (i.e., $d \geq h$), then the horizontal distance is

$$R = h \tan\frac{\theta}{2} \text{ (m)} \quad (7)$$

as shown in Figure 2(a)

(b) If the vertical component of the slant distance *h* is greater than water depth *d* (i.e., $h > d$), then the horizontal distance is

$$R = d \tan\frac{\theta}{2} \text{ (m)} \quad (8)$$

as shown in Figure 2(b)

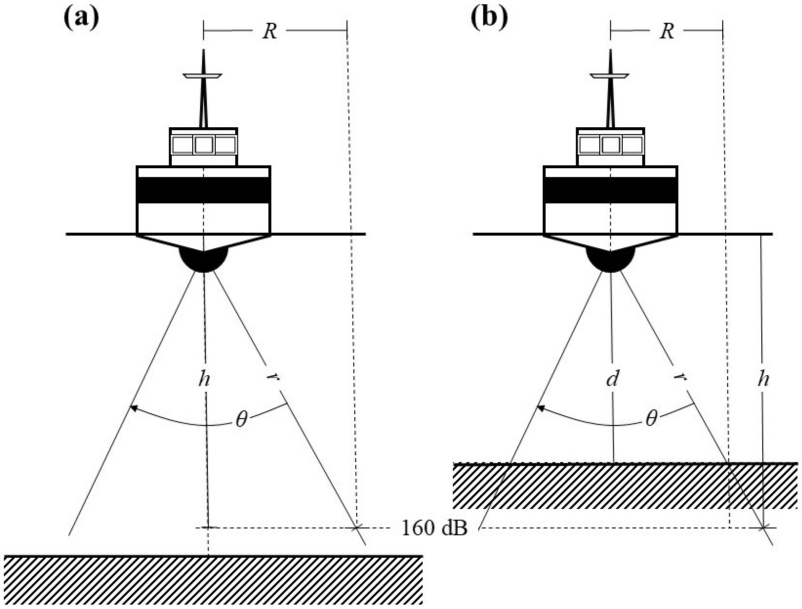

Figure 2. Schematic diagrams showing horizontal impact distance *R* in relation to acoustic beamwidth *θ* where beam is directed downward. (a) Water depth *d* is greater than the vertical component of slant distance *h*, and (2) water depth *d* is less than the vertical component of slant distance *h*.

References:

Ainslie, M.A. (2010). Principle of Sonar Performance Modelling. Berlin: Springer.

Crocker, S.E., and F.D. Fratantonio. (2016). Characteristics of Sounds Emitted During High-Resolution Marine Geophysical Surveys. NUWC-NPT Technical Report 12,203. 24 March 2016, Naval Undersea Warfare Center Division, Newport, RI.