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Issues and Opportunities for Inverting a Simple Seafloor Description for Shallow Oceans

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ABSTRACT

With suitable processing, a broadband acoustic signal received at a short range in a shallow ocean may be used to invert the Weston α parameter (Weston, D. E., J. Sound Vib. 18, 271-287, 1971) appropriate for the local seabed. Based on this, adequate simulations of sound transmission to much longer range may be obtained. The broadband signal may be an impulse, or continuous random emission, across the frequency band of interest. As no sensor calibration is required for the technique, there is considerable opportunity for legacy time series data to be re-processed to carry out the inversion. Application of the inversion technique is demonstrated using previously unpublished legacy impulse data, and simulations of transmission to longer range are obtained. These simulations are then compared with legacy at-sea measurements of transmission. Both the inversion technique itself and the application of the inverted data are not without a number of issues. These are considered with reference to practical cases.

1 INTRODUCTION

For small grazing angles β less than the critical angle, the loss in dB on each bottom reflection, the Bottom Loss (BL), may be approximated as proportional to the grazing angle. BL then becomes $F\beta\,\mathrm{dB}$, where the "bottom loss parameter", $F\,\mathrm{dB/radian}$, describes the seafloor. The theoretical basis for its existence was shown by Weston (1971) and $F\,\mathrm{dB/radian}$ has become known as the Weston α parameter. Smith (1971) identified that the decay of acoustic energy following an impulsive signal trended towards exponential, for which dB values decrease linearly with time, and determined a link between the decay time and the equivalent of $F\,\mathrm{dB/radian}$, thus enabling an inversion of the latter. Subsequently, Jones and Clarke (2010) showed that the inversion of $F\,\mathrm{dB/radian}$ may be achieved using a spectral-based technique, thus allowing greater flexibility in the use of at-sea data. Using this spectral technique, the bottom loss parameter may be inverted using the received signal from an explosive impulse, a finite duration coherent sweep, or continuous random signal, across the frequency band of interest. As no sensor calibration is required for the technique, there is considerable opportunity for legacy time series data to be re-processed to carry out the inversion.

2 SPECTRAL INVERSION TECHNIQUE

The bottom loss parameter F may be inverted as

$$F \approx \frac{27.3\,D\,\Delta f_h}{c_w}\quad \mathrm{dB/radian} \tag{1}$$

where D is ocean depth, m, c_w is seawater sound speed, m/s. The value of Δf_h, Hz, corresponding with $\rho_{|p|}(\Delta f)=0.5$, is obtained from the sound pressure amplitude values from the real part of an FFT spectrum of a received time series, by implementing the following expression for a normalised autocorrelation

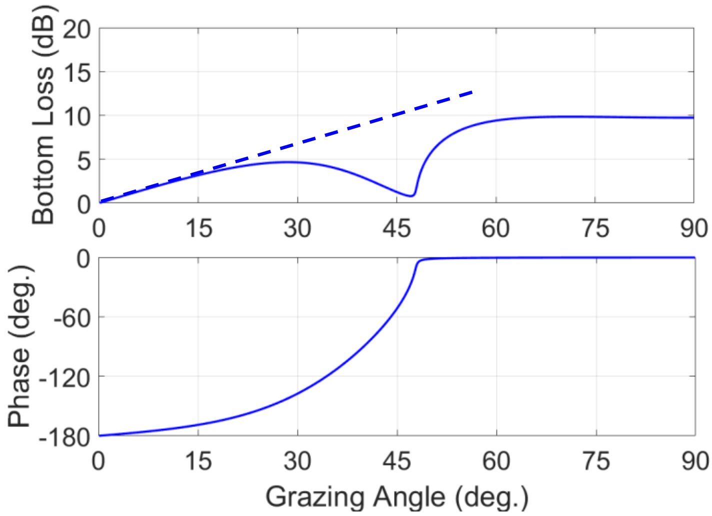
$$\rho_{|p|}(\Delta f)=\frac{\langle |p(f)||p(f+\Delta f)|\rangle-\langle |p(f)|\rangle^2}{\langle |p(f)|^2\rangle-\langle |p(f)|\rangle^2}. \tag{2}$$

With application to typical broadband data received from a Signal Underwater Sound (SUS) explosive impulse, a value of F may be obtained for each octave band. This level of resolution obviously misses features occurring over small spans of grazing angle, if these exist. Also, the SUS signal includes a bubble pulse, so to avoid contamination, the time period prior to this, only, was used for the inversion which is the example for this paper.

2.1 Application of Technique

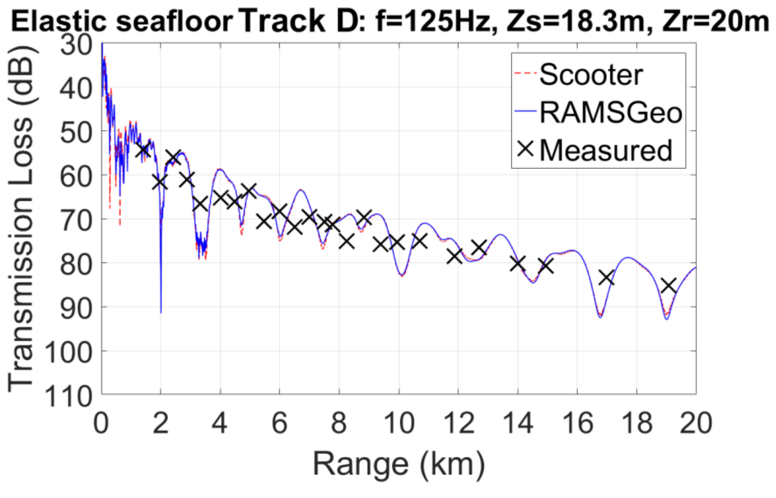
The authors applied the technique to previously unpublished legacy SUS data for a shallow ocean track not considered before, Track D, yielding a value F =13.0 dB/radian for data across the 125 Hz octave band. The receiver was at 3.32 km range. A set of geoacoustic parameters for an elastic seafloor half-space was then selected to match the inverted reflectivity. Figure 1 shows that the resulting Bottom Loss values at small angles less than about 20° provided an excellent match to a line of slope 13.0 dB/radian.

Transmission Loss (TL) measurements obtained by DSTG were then compared with TL estimates obtained using models Scooter and RAMSGeo with the geoacoustic parameters. The estimated TL values, based on the SUS data, compare well with the measurements, which are integrated over the 1/3rd octave band for 125 Hz.



Source (DSTG)

Figure 1: Reflection Bottom Loss & phase angle from geoacoustic properties selected to match inverted bottom loss parameter *F*, Track D: 125 Hz.



Source (DSTG)

Figure 2: TL measured along Track D in 1/3rd octave band centred at 125 Hz vs TL at 125 Hz based on bottom loss parameters matching inverted parameter *F*, using start-of-track sound speed profile.

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