Introduction:

The purpose of this document is to collect in one place the computed transmission loss for Test Cases 1 - 4, which accompany the computer program COUPLE07. The Test Cases are discussed to the extent that seems appropriate: Test Cases 1 and 2 have already been covered in [1] so their discussion is minimized.

Test Case 1:

Test Case 1 is Test Case 3b from the first Parabolic Equation Workshop [2, pp. 46-54] and is also discussed in [1, pp. 355-357]. The water layer is 100 m deep and has a sound speed of 1500 m/s and a density of 1.0 gm/cm^3. The sediment has a sound speed of 1590 m/s, an attenuation of .5 dB/wavelength and a density of 1.2 gm/cm^3. The transmission loss for Test Case 1 is shown in Fig. 1.

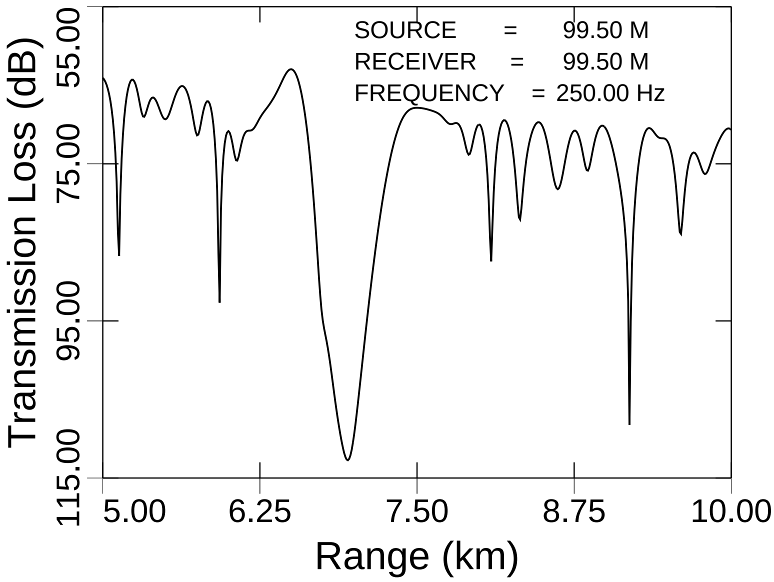

Figure 1. Transmission loss versus range for Test Case 1.

Test Case 2:

Test Case 2 is the Acoustical Society of America benchmark wedge problem [3] and is discussed in [1, pp.396-399]. The water layer has a sound speed of 1500 m/s and a density of 1.0 gm/cm^3. The sediment has a sound speed of 1700 m/s, an attenuation of .5 dB/wavelength and a density of 1.5 gm/cm^3. The bottom slopes from a depth of 200 m, at the source, to a depth of 0 m at a range of 4 km. The transmission loss, for this case, is computed by two methods: The single scatter approximation and the one-way pressure matching method, which fails to conserve energy. The two results are contrasted in Fig. 2.

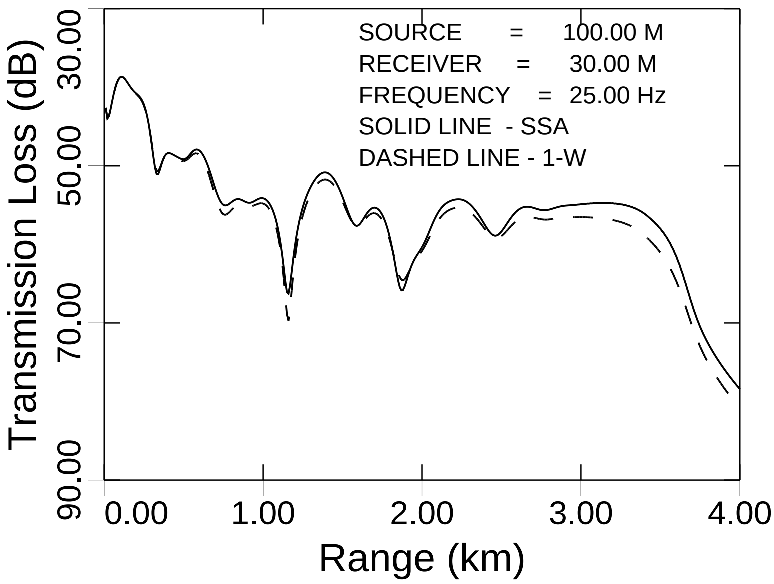

Figure 2. Transmission loss versus range for Test Case 2. The solid curve is the single scatter approximation and is indistinguishable from the two-way solution. The dashed curve is the one-way pressure matching solutions.

Test Case 3:

Test Case 3 is an example from [4] and consists of a square wave corrugation of the water-sediment interface with a height of 10 m and a period of .1 km, extending from 5-10 km. The water layer has a sound speed of 1500 m/s and a density of 1.0 gm/cm^3. The sediment has a sound speed of 1704.5 m/s, an attenuation of .5 dB/wavelength and a density of 2.5 gm/cm^3. The high sediment density, combined with the square wave corrugation, creates a sequence of impedance mismatches and results in significant multiple scattering. The results in [4] are under sampled in range and mode number. This has been corrected in Test Case 3 by using 120 modes and sampling the field every 10 cm to capture the interference in the multiply scattered field. The transmission loss is computed by two methods: The two-way solution, which computes multiple scattering, and the single scatter approximation. Both methods use an absorber at the source range (IREFL=1). The two results are compared in Fig. 3.

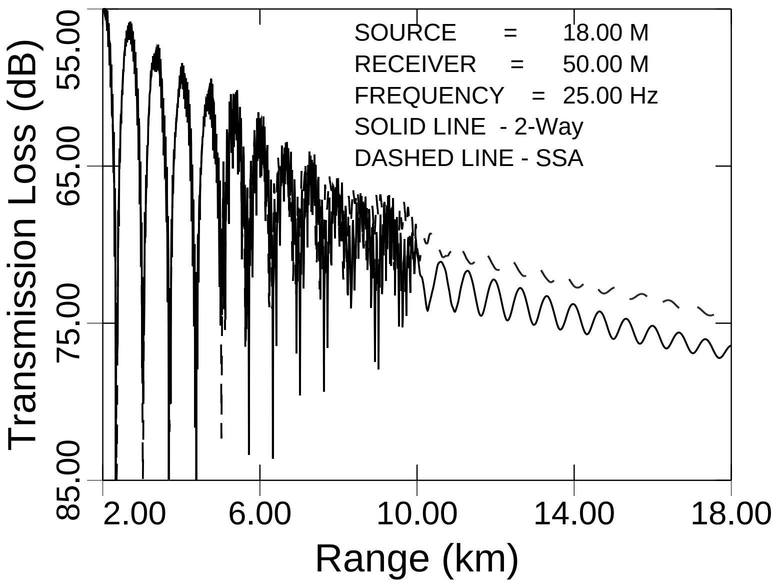

Figure 3. Transmission loss versus range for Test Case 3. The solid curve is the two-way solution while the dashed curve is the single scatter approximation.

Test Case 4:

Test Case 4 is Test Case 4c from the first Parabolic Equation Workshop [2, pp. 54-59]. The frequency for this problem is 25 Hz and the source is at a depth of 600 m in 3410 m of water. The sound velocity profile, at the source, is shown in Fig. 4.

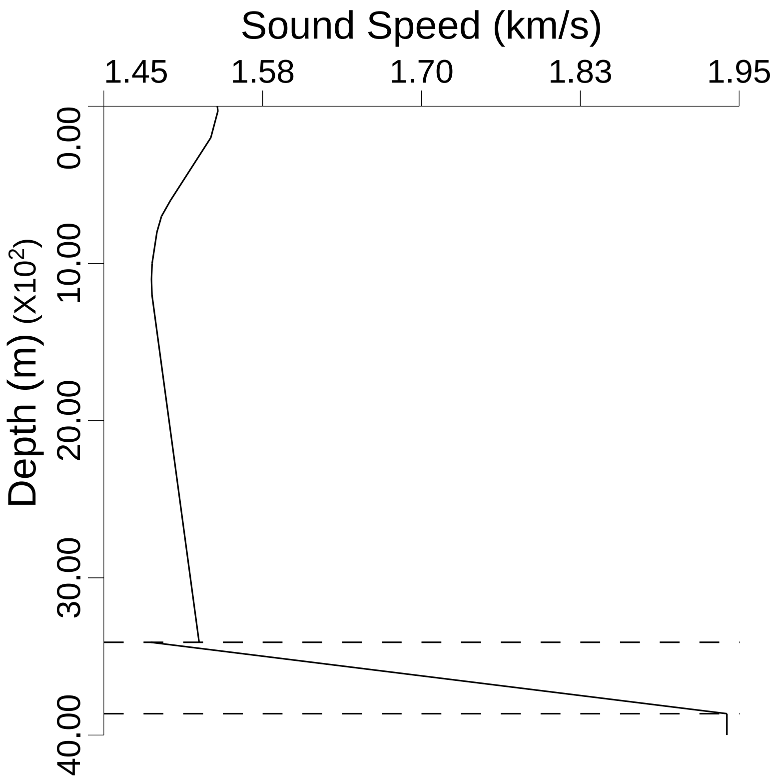

Figure 4. Sound speed profile at range zero for Test Case 4

The sound speed at the top of the sediment is .975 times the sound speed at the bottom of the water column (2.5% less). The sediment layer is 454 m thick with a constant gradient. The sound speed at the bottom of the sediment layer is 1.305 times the sound speed at the top of the sediment. The density in the sediment is 1.5 gm/cm^3 and the sediment has an attenuation of .0258 dB/wave length. An absorber starts at 3864 m.

Test Case 4c consists of a deep basin, an upslope and a shallow shelf. The bottom is flat for the first 150 km. The depth then decreases from 3410 to 200 m in the interval range 150 to 200 km. The slope is about 3.67^o. The program COUPLE07 used 300 modes and the slope was approximated with 986 steps. The single scatter approximation is used for this case. The transmission loss for the last 25 km of the slope and the first 25 km of the shelf, at a depth of 150 m, is shown in Fig. 5.

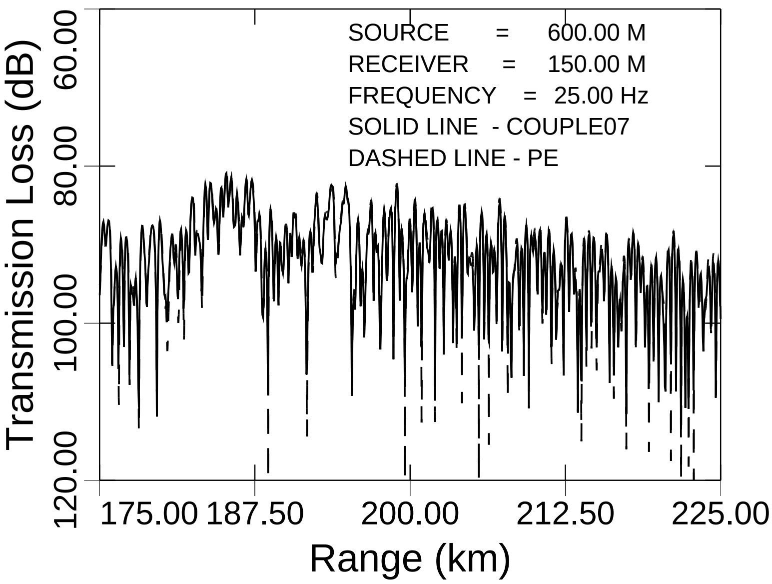

Figure 5. Transmission loss versus range for a receiver at 150 m. The solid curve was computed with COUPLE07 using the single scatter approximation. The dashed curve was computed using a double precision version of the parabolic equation model ram [5]. The two curves are indistinguishable except in the deep nulls.

Test Case 4c specified that the field, at the 150 m receiver, be intensity averaged over a 1 km range window and that the resulting transmission loss be plotted on the range interval 175 to 225 km. The results from the various parabolic equation models, presented at the Workshop [2, pp. 65-66], showed a 10 dB uncertainty in the computed transmission loss in 1982. The correct range averaged transmission loss is shown in Fig. 6.

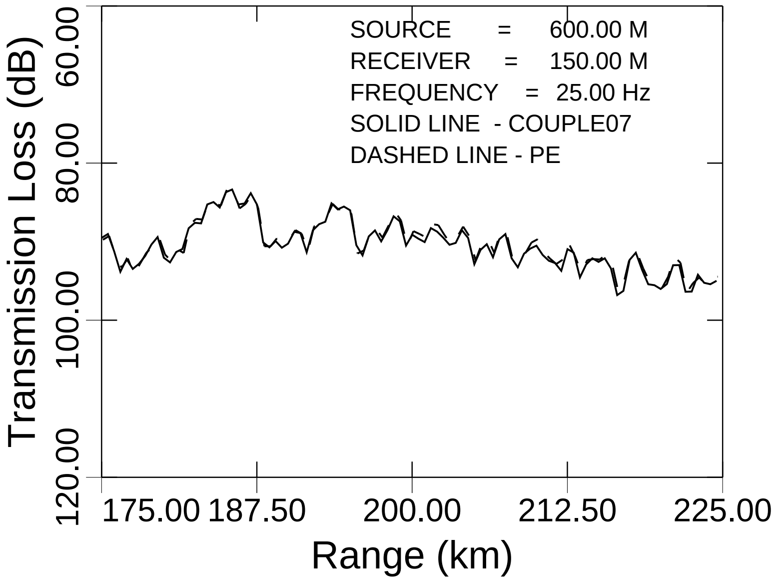

Figure 6. Range averaged (1 km) transmission loss from Fig. 5.

References:

1. F. B. Jensen, W. A. Kuperman, M. B. Porter and H. Schmidt, *Computational Ocean Acoustics* (AIP Press, New York, 1994).

2. J. A. Davis, D. White and , R. C. Cavanagh, "NORDA Parabolic Equation Workshop," NORDA Technical Note 143 (Naval Ocean Research and Development Activity, Stennis Space Center, MS, 1982).

3. F. B. Jensen and C. M. Ferla, "Numerical solutions of range-dependent benchmark problems in ocean acoustics," J. Acoust. Soc. Am. **87**, 1499-1510 (1990).

4. R. B. Evans and K. E. Gilbert, "The periodic extension of stepwise coupled modes," J. Acoust. Soc. Am. **77**, 983-988 (1985).

5. M. D. Collins, "A split-step Pade' solution for the parabolic equation method," J. Acoust. Soc. Am. **93**, 1736-1742 (1993).