The KRAKEN Normal Mode Program

Michael B. Porter
SACLANT Undersea Research Centre

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Chapter 4

Running the Program

The KRAKEN program is actually part of a complete package of modeling tools referred to as the Acoustics Toolbox and structured as shown in Fig. 4.1. Besides the KRAKEN normal mode model, there is also a 1) ray/beam tracing model, BELLHOP, 2) an FFP (spectral integral), SCOOTER, and 3) a time-domain FFP model, SPARC.

The models take as input a user-provided environmental file (ENVFIL) to describe the problem. This file has the same format for all models. PLOTSSP can be used to produce a plot of the sound speed profile defined in the environmental file.

The models then produce a binary 'shade' file (SHDFIL) that contains calculated pressure fields. PLOTFIELD can be used to convert the pressure to transmission loss and produce a color or grey shade plot of the transmission loss over range and depth. The program PLOTSLICE is used to plot a slice of the field along a fixed receiver depth. Additional programs exist for using the shade files to do matched-field processing, to compute a probability of detection or a radius of detection.

There are utilities available for converting between the NRL shade file format and the SACLANTCEN format (TONRL and TOSAC). This allows the SACLANTCEN models to be plotted using PLOTFIELD and PLOTSLICE for intermodel comparisons. There are also utilities for converting the shade file to an ASCII format (TOASC) and back to their original binary format (TOBIN). These programs allow you to transfer files between computers with incompatible binary files by transferring an ASCII file instead.

While the basic structure is as shown in Fig. 4.1, each of the models has additional plotting routines which are unique to it. For instance, the BELLHOP ray model produces rays and so it has a ray plotting program, while the KRAKEN normal mode produces modes and so it has a mode plotting program. In this chapter, we focus on the description of the KRAKEN component, however, the other models are also discussed (briefly).

Most of the development work has been done on a VAX using VMS Fortran but careful thought has been given to portability. The following changes are necessary to run KRAKEN under UNIX using the f77 compiler:

1. Change the logical record length used for opening files. VMS uses longwords (4 bytes) most other systems seem to use bytes.

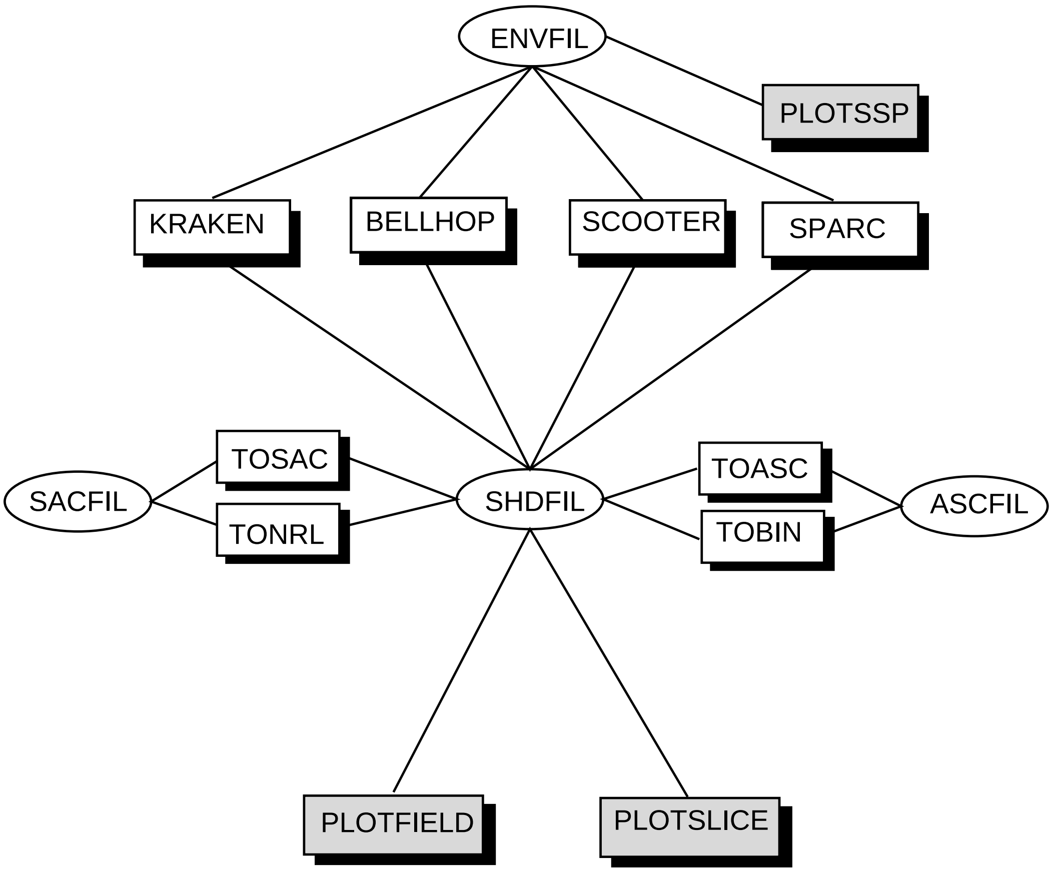

Figure 4.1: Structure of the Acoustics Toolbox.

2. Change the timing routines in TIME.FOR.

3. Change the machine constants in SLATECBESSEL.FOR *or* eliminate the Twersky ice-scatter option which uses those routines. This is done by replacing TWERSK.FOR with TWERSKYFUSE.FOR. With the latter routine it is no longer necessary to link with SLATECBESSEL and MATHIEU.

4. Apparently there is no way for the Unix system to retrieve a record length for a file automatically. You will need to modify the mode-file format to include the record length, do a preliminary read to obtain the record length, then re-open the file with the correct record length.

5. If you have core space problems, change the parameter MAXN which controls the maximum number of mesh points in depth. In KRAKEN this and other parameters are defined in the include-file COMMON.FOR . Similar include-files exist for KRAKENC, SCOOTER, SPARC, and BELLHOP.

4.1 Structure of the KRAKEN model

A schematic of the KRAKEN program structure is shown in Fig. 4.2. At the first level we see that KRAKEN actually consists of three different models KRAKEN, KRAKENC and KRAKEL. KRAKENC and KRAKEL are for more sophisticated users with special requirements. The differences are discussed in more detail in the KRAKEN.HLP file below.

A transmission loss calculation involves a two-step process running in sequence 1) KRAKEN to calculate the modes and 2) PLOTTLR or PLOTTLD to sum up the modes and plot TL versus range or depth. In addition, PLOTMODE can be run to look at the individual modes and PLOTGRN can be used to calculate a Green's function.

Producing a grey shade or color plot of transmission loss involves a three-step process running in sequence 1) KRAKEN to calculate the modes and 2) FIELD to sum the modes and calculate the pressure field, and 3) PLOTFIELD to plot the results.

Three-dimensional calculations follow a similar sequence but using FIELD3D instead of FIELD to sum the modes. As discussed in Chap. 2, 3-D calculations use a triangular patchwork over the ocean bottom that is defined in an input field-parameter file (FLPFIL). PLOTTRI is used to plot the triangular patchwork. Besides the 3-D pressure fields, FIELD3D also produces output describing the horizontal refraction which can be plotted using PLOTRAYXY.

Detailed information on how to run KRAKEN is contained in a sequence of help files included with the source code. These help files are reproduced below. Note that all the plot programs require a few lines providing axis information (minimum, maximum, interval for tick marks and axis lengths). This information can be read from a file however it is generally convenient to place the data directly in the command file used to execute the program. Command files for the VAX (with the extension '.COM') are provided with the program.

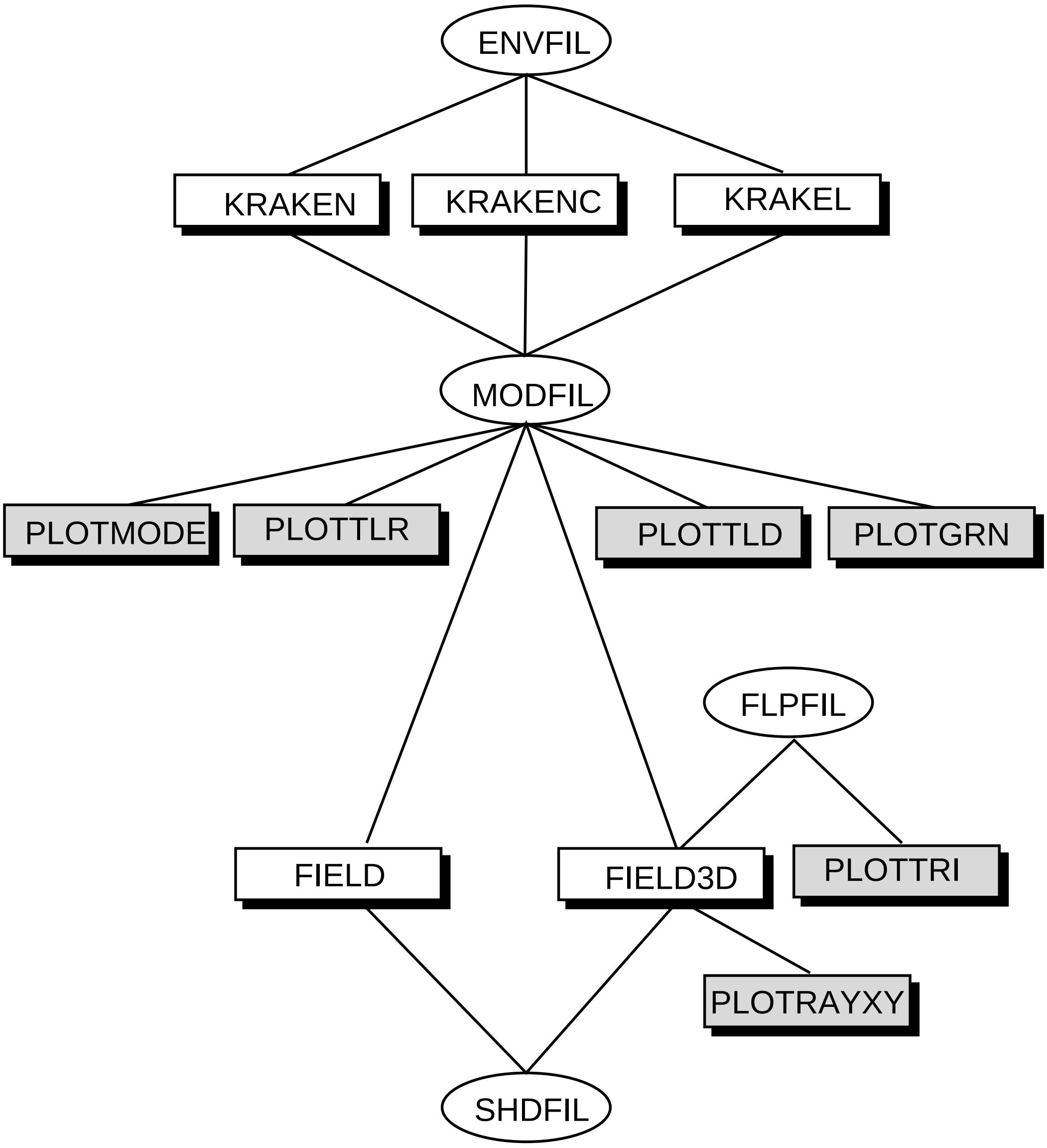

Figure 4.2: Structure of the KRAKEN model.

4.2 The Main Program

4.2.1 notes.hlp

KRAKEN is a normal mode program for range-varying environments in either cartesian (line sources) or cylindrical coordinates (point sources). The basic method is described in

Porter, Michael B. and Reiss, Edward L., "A numerical method for ocean-acoustic normal modes", JASA 76, 244–252 (1984).

Porter, Michael B. and Reiss, Edward L., "A numerical method for bottom interacting ocean acoustic normal modes", JASA 77, 1760–1767 (1985).

Range-dependent solutions are obtained by using optionally adiabatic or coupled mode theory.

The following modules are part of the package.

```
GROUP I: MODE COMPUTATIONS:


  KRAKEN    Solves for the modes and writes them to disk.
            Elastic media are allowed but material attenuation
            in an elastic medium is ignored.

  KRAKENC   A version of KRAKEN which finds the eigenvalues in the
            complex plane.  KRAKEN uses perturbation theory to
            obtain imaginary parts of the eigenvalues while KRAKENC
            computes the complex eigenvalues exactly.

            KRAKENC runs about 3 times slower but is necessary for
            leaky mode computations or for including material
            attenuation in elastic media.  Internally KRAKENC replaces
            elastic layers by an equivalent reflection coefficent.
            For this reason, you cannot use KRAKENC to look at
            fields within the elastic layers.

  KRAKEL    Analogous to KRAKENC but also computes elastic
            displacements and stresses for elastic media.
            KRAKEL is seldom used and tends to not be kept
            up-to-date.

GROUP II: BASIC PLOTTING ROUTINES:


  PLOTSSP   Plots the sound speed profile.

  PLOTMODE  Plots selected modes.
```

PLOTGRN Plots the Green's funtion for the depth separated wave equation for a particular source/receiver combination.

PLOTTLR Plots transmission loss versus range.

PLOTTLD Plots transmission loss versus depth.

PLOTTRI Plots the triangular elements used for 3-D field calculations.

GROUP III: FIELD COMPUTATIONS:

FIELD Computes fields on a vertical array over a specified range and for a series of source depths. Individual phones in the array may be displaced from the vertical. Range dependence is handled by either adiabatic or one-way coupled mode theory.

FIELD3D Computes field for a three-dimensionally varying SSP using adiabatic mode theory.

GROUP IV: PLOTTING ROUTINES THAT USE GROUP III PROGRAM OUTPUT:

PLOTFIELD Plots tranmission loss in plan or elevation, i.e. an (x,y) plot or an (r,z) plot.

PLOTSLICE Plots overlays of transmission loss versus range curves by extracting slices from several shade files.

PLOTRAYXY Plots the ray paths of the Gaussian beams generated during 3D field calculations.

The various programs for computing fields (GROUP III) are only needed for PLOTFIELD, or for special user programs (e.g. ambiguity surfaces). PLOTTLR and PLOTTLD compute the field internally and therefore do not need a shade file from FIELD to run.

The following extensions are used with these programs:

```
  .FOR        The FORtran source code
  .HLP        A HeLP file documenting the module
  .COM        A COMmand file which runs the module
  .LNK        A command file which performs a LiNK

All user input in all modules is read using list-directed I/O.
Thus data can be typed in free-format using space, tabs, commas
or slashes as delimeters. Character input should be enclosed in
single quotes like this: 'CHARACTER INPUT'.

You will see the '/' character in a number of the input files.
This terminates an input line causing the program to use
default values.

---------------------------------------------------------------


                 ***** INSTALLATION NOTES *****

There is a command file for each of the programs in this package
which assigns necessary input files to the appropriate Fortran
unit number used by that program.  In order to simplify the installation,
these command files make use of logical names for certain directories.
The logical names are in turn defined in a single file call AT_INIT.COM
which is the ONLY file which needs to be customized for a new installation.

The following symbols and logical names for directories are used with
the KRAKEN command files:

   AT:    This is the Acoustics Toolbox directory which contains
          command files for running KRAKEN and other models
          in the toolbox.

   KRAK:  The KRAKEN source code

   MISC:  Miscellaneous scientific subroutines, e.g.
          root-finders, linear equation solvers, ...

   GLOB:  Global routines, that is, routines which operate on
          shade files.  These routines operate on the output of
          a number of different propagation codes including
          KRAKEN, FSTFLD, BELLHOP, SCOOTER and SPARC.

   SCR:   A directory for scratch files.
```

```
  DISSPLA is a symbol which points to the DISSPLA plotting
          library.


The following is an example of how these might be defined under
the VAX VMS operating system:


$ DEFINE    AT          US:[PORTER.AT]
$  DEFINE   BELL        US:[PORTER.AT.BELLHOP]
$  DEFINE   GLOB        US:[PORTER.AT.GLOBAL]
$  DEFINE   KRAK        US:[PORTER.AT.KRAKEN]
$  DEFINE   MAN         US:[PORTER.AT.MANUAL]
$  DEFINE   MISC        US:[PORTER.AT.MISC]
$  DEFINE   SCO         US:[PORTER.AT.SCOOTER]
$ DEFINE  SCR           US:[PORTER.SCR]
$ !
$ DISSPLA == "[DIS11.LIB]DISLIB/L, INTLIB/L, DISLIB/L, HCBS/L"

----------------------------------------------------------------

                  ***** HOW TO RUN KRAKEN *****


  0. Starting out for the first time? Take a look at
     CLINK.COM for a compile and link of the whole package.

  1. Create the environmental file for your problem, following the
     directions in KRAKEN.HLP.

  2. Run KRAKEN (or KRAKENC).  On the VAX this is done by typing
     either

     @KRAKEN filename
        or
     SUBMIT KRAKEN/PAR=filename

     where "filename" is the environmental file.
     The KRAKEN.HLP file details the differences between the
     KRAKEN and KRAKENC.

  3. You now have several choices (all the GROUP II programs):

     a. Plot tranmission loss:
```

```
@PLOTTLR filename
```

b. Plot the modes:

```
@PLOTMODE filename
```

c. Plot the sound speed profile (actually, this can be done even before running KRAKEN):

```
@PLOTSSP filename
```

d. Plot the pressure field as a function of range and depth. This is a 2-step process:

```
@FIELD filename
@PLOTFIELD filename
```

In general, you'll have to modify each command file before running it to provide the appropriate inputs as described in the help file for each program.

Once the modes are created by KRAKEN or KRAKENC you can run the above plot programs in any sequence or as often as you like.

4.2.2 kraken.hlp

KRAKEN is the main program. It takes an environmental file, computes the modes, and writes them to disk for use by other modules. A print file is also produced, echoing the user input.

KRAKENC is a complex arithmetic version (hence the C in KRAKENC) of KRAKEN. By working in the complex domain, loss mechanisms such as ice scatter and material absorption may be included 'exactly' rather than perturbatively. In addition, leaky modes may be computed. The price of this non-perturbative treatment is a slowdown in speed by approximately a factor of 4. This factor principally represents the difference between complex and real arithmetic.

A further slow down by a factor of 2 or more may occur it the Twersky scatter option is used in KRAKENC. The calculation of the Twersky scatter function can require significant CPU time; enough to actually be a dominant part of the cost of computing the modes. KRAKEN incorporates the scatter perturbatively and is much less sensitive to the cost of Twersky scatter.

KRAKEN does not at allow for losses in elastic media due to material attenuation. Thus, for attenuating elastic media, KRAKENC should be used.

```
Files:

        Name           Unit         Description
Input
        *.ENV            1       ENVironmental data
        *.BRC           10       Bottom   Refl. Coef.  (optl)
        *.TRC           11       Top      Refl. Coef.  (optl)
        *.IRC           12       Internal Refl. Coef.  (optl)
Output
        *.PRT            6       PRinT file
        *.MOD           20       MODe  file

----------------------------------------------------------

EXAMPLE AND DESCRIPTION OF ENV FILE:

 'FRAMIV Twersky S/S ice scatter'        ! TITLE
 50.0                                    ! FREQ (Hz)
 4                              ! NMEDIA
 'NSF'                          ! OPTIONS
 0.0092  8.2  5.1               ! BUMDEN (1/m)  ETA (m)  XI (m)
 750  0.0  3750.0               ! NMESH  SIGMA (m)  Z(NSSP)
     0.0  1436.0  0.0  1.03/    ! Z(m)  CP  CS(m/s)  RHO(gm/cm3)
    30.0  1437.4 /
    50.0  1437.7 /
    80.0  1439.5 /
```

```
  100.0  1441.9 /
  125.0  1444.6 /
  150.0  1450.0 /
  175.0  1456.1 /
  200.0  1458.4 /
  250.0  1460.0 /
  300.0  1460.5 /
  350.0  1460.6 /
  400.0  1461.0 /
  450.0  1461.5 /
  500.0  1462.0 /
  600.0  1462.9 /
  700.0  1463.9 /
  800.0  1464.8 /
  900.0  1465.8 /
 1000.0  1466.7 /
 1100.0  1467.0 /
 1200.0  1469.0 /
 1300.0  1469.5 /
 1400.0  1471.8 /
 1600.0  1474.5 /
 1800.0  1477.0 /
 2000.0  1479.6 /
 2500.0  1487.9 /
 3750.0  1510.4 /
35  0.0  3808.33
 3750.0  1504.6     0.0   1.50   .15  0.0
 3808.33 1603.07 /
35  0.0  3866.66
 3808.33 1603.07    0.0   1.533  .15  0.0
 3866.66 1701.53 /
35  0.0  3925.0
 3866.66 1701.53    0.0   1.566  .15  0.0
 3925.0  1800.0 /
'A'  0.0                     ! BOTOPT  SIGMA (m)
 3925.0  1800.0     0.0   1.60   .15  0.0
0.0  1504.0                  ! CLOW  CHIGH (m/s)
300.0                        ! RMAX (km)
1                            ! NSD
100.0 /                      ! SD(1:NSD) (m)
1                            ! NRD
200.0 /                      ! RD(1:NRD) (m)


---------------------------------------------------------------
```

```
DESCRIPTION OF INPUTS:

The following can be repeated as many times as wanted in a single ENVFIL.
KRAKEN and KRAKENC will generate a separate MODFIL for each case stopping when it
detects an end-of-file.

(1) - TITLE

      Syntax:
         TITLE
      Description:
         TITLE: Title of run enclosed in sinqle quotes.


(2) - FREQUENCY

      Syntax:
         FREQ
      Description:
         FREQ: Frequency in Hz.


(3) - NUMBER OF MEDIA

      Syntax:
         NMEDIA (<20)
      Description:
         NMEDIA: Number of media.

      The problem is divided into media within which it is
      assumed that the material properties vary smoothly. A new
      medium should be used at fluid/elastic interfaces or at
      interfaces where the density changes discontinuously. The
      number of media in the problem is defined excluding the
      upper and lower half-space.


(4) - OPTIONS

      Syntax:
         OPTION
      Description:
         OPT(1:1): Type of interpolation to be used for the SSP.
                   'C' for C-linear,
```

```
          'N' for N2-linear (n the index of refraction),
          'S' for cubic Spline,
          'A' for Analytic.  The user must modify the
              analytic formulas in PROFIL.FOR then
              compile and link.

    If your not sure which option to take, I'd suggest
    you use 'C' or 'N'.  Practically, you can pick
    either one: the choice has been implemented to
    facilitate precise intermodel comparisons.

    Option 'S' is a little dangerous because splines
    yield a poor fit to certain kinds of curves,
    e.g. curves with sharp bends.  If you insist
    on splines, you can fix a bad fit by dividing the
    water column into two 'media' at the bend.

    Run PLOTSSP to check that the SSP looks the way you
    thought it should. Apart from potential typos,
    this will also show up fit-problems.

OPT(2:2): Type of top boundary condition.
          'V' VACUUM above top.
          'A' ACOUSTO-ELASTIC half-space.
              Requires another line as described in
              block (4a).
          'R' Perfectly RIGID.
          'F' Reflection coefficient from a FILE
              (available in KRAKENC only). Requires
              additional lines as described in
              block (4c).
          'S' for Soft-boss Twersky scatter.
          'H' for Hard-boss Twersky scatter.
          'T' for Soft-boss Twersky scatter, amplitude
              only.
          'I' for Hard-boss Twersky scatter, amplitude
              only. The Twersky scatter options require
              another line as described in block
              (4c). Mnemonically, T, I options are one
              letter after S, H in the alphabet. Current
              wisdom is that option T is most
              appropriate for ice scatter.

           For open ocean problems option 'V' should be
           used for the top BC.  The Twersky options
```

```
                are intended for under-ice modeling.

   OPT(3:3): Attenuation units.
             'N' Nepers/m.
             'F' dB/(kmHz)       (F as in Freq. dependent)
             'M' dB/m            (M as in per Meter)
             'W' dB/wavelength   (W as in per Wavelength)
             'Q' quality factor.
             'T' Thorp attenuation formula.  This overrides
                 any other attenuations specified.

             KRAKEN ignores material attenuation
             in elastic media. (KRAKENC treats
             it properly).

   OPT(4:4): Added volume attenuation.
             'T' Thorp attenuation formula.

   OPT(5:5): Slow/robust root-finder.
             '.' As in: I want all the modes and I don't
                 care how long it takes. Period.
                 (Available in KRAKENC only.)
                 In certain problems with elastic layers
                 the old root-finder has been known to
                 skip modes.


(4a) - TOP HALFSPACE PROPERTIES

      Syntax:
         ZT  CPT  CST  RHOT  APT  AST
      Description:
         ZT:   Depth (m).
         CPT:  Top P-wave speed (m/s).
         CST:  Top S-wave speed (m/s).
         RHOT: Top density (g/cm3).
         APT:  Top P-wave attenuation. (units as given in Block 2)
         AST:  Top S-wave attenuation. (  "   "    "    "   "   ")

         This line should only be included if OPT(2:2)='A', i.e.
         if the user has specified a homogeneous halfspace for
         the top BC.


(4b) - TOP REFLECTION COEFFICIENT
```

```
Syntax:
   NTHETA
   THETA(1)       RMAG(1)       RPHASE(1)
   THETA(2)       RMAG(2)       RPHASE(2)
     .
     .
     .
   THETA(NTHETA)  RMAG(NTHETA)  RPHASE(NTHETA)

Description:
   NTHETA:   Number of angles.
   THETA():  Angle.
   RMAG():   Magnitude of reflection coefficient.
   RPHASE(): Phase of reflection coefficient (degrees).

Example:
   3
   0.0   1.00  180.0
   45.0  0.95  175.0
   90.0  0.90  170.0

These lines should be contained in a separate '.TRC' file.
This file is only required if OPT(2:2)='F', i.e. if the
user has specified that the top BC is read from a '.TRC'
(Top Reflection Coefficient) file.

This option for tabulated reflection coefficients is
somewhat experimental at this time. I haven't worried about
the multivalued character of the phase function: choose
your reference and make sure the phase varies continuously.
A complicated reflection coefficient may well cause
problems for the mode-finder.
```

(4c) - TWERSKY SCATTER PARAMETERS

```
Syntax:
   BUMDEN  ETA  XI
Description:
   BUMDEN: Bump density (ridges/km).
   ETA:    Principal radius 1 (m).
   XI:     Principal radius 2 (m).

This line should only be included when one of the
```

```
      Twersky-scatter options is selected.

(5) - MEDIUM INFO

      Syntax:
         NMESH  SIGMA  Z(NSSP)
      Description:
         NMESH:   Number of mesh points to use initially.
                  The number of mesh points should be about 10
                  per vertical wavelength in acoustic media. In
                  elastic media, the number needed can vary quite
                  a bit; 20 per wavelength is a reasonable
                  starting point.

                  The maximum allowable number of mesh points is
                  given by 'MAXN' in the dimension statements.
                  At present 'MAXN' is 50000.  The number of mesh
                  points used depends on the initial mesh and the
                  number of times it is refined (doubled).  The
                  number of mesh doublings can vary from 1 to 5
                  depending on the parameter RMAX described
                  below.

                  If you type 0 for the number of mesh points,
                  the code will calculated NMESH automatically.

         SIGMA:   RMS roughness at the interface.

         Z(NSSP): Depth at bottom of medium (m).
                  This value is used to detect the last SSP point
                  when reading in the profile that follows.

(5a) - SOUND SPEED PROFILE

      Syntax:
         Z(1)     CP(1)     CS(1)     RHO(1)     AP(1)     AS(1)
         Z(2)     CP(2)     CS(2)     RHO(2)     AP(2)     AS(2)
          .
          .
          .
         Z(NSSP)  CP(NSSP)  CS(NSSP)  RHO(NSSP)  AP(NSSP)  AS(NSSP)
      Description:
         Z():     Depth (m).
                  The surface starts at the first depth point
                  specified. Thus if you have say, XBT data which
```

```
              starts at 50 m below the surface, then you'll
              need to put in some SSP point at 0 m, otherwise
              the free-surface would be placed at 50 m giving
              erroneous results. The points Z(1) and Z(NSSP)
              MUST correspond to the depths of interfaces
              between media.

    CP():     P-wave speed (m/s).
    CS():     S-wave speed (m/s).
    RHO():    Density (g/cm3).
              Density variations within an acoustic medium
              are at present ignored.
    AP():     P-wave attenuation (units as given in Block 2)
    AS():     S-wave attenuation (  "   "    "    "   "   ")
```

These lines should be omitted when the 'A' option is used (indicating that an analytic profile is supplied by a user written subroutine).

The '/' character signals that the remaining data on the line is the same as in the previous line of SSP data. For the very first line the default or 'previous' line is:

```
0.0 1500.0 0.0 1.0 0.0 0.0
```

This block should be repeated for each subsequent medium.

(6) - BOTTOM BOUNDARY CONDITION

```
Syntax:
   BOTOPT  SIGMA
Description:
   BOTOPT: Type of bottom boundary condition.
           'V' VACUUM below bottom.
           'A' ACOUSTO-ELASTIC half-space.
               Requires another line with the half-space
               parameters.  The format is the same as that
               used for specifying the top halfspace BC.
           'R' Perfectly RIGID.
           'F' reflection coefficient from a FILE (available
               in KRAKENC only). Requires a Bottom
               Reflection Coefficient file with
               extension '.BRC'.  The format is the same as
```

```
                that used for a Top Reflection coefficient.
            'P' Precaculated internal reflection coefficient
                from a FILE (available in KRAKENC only).
                These files are generated using BOUNCE.
            Option 'A' is generally used for ocean bottom
            modeling.
    SIGMA:  Interfacial roughness (m).


(7) - PHASE SPEED LIMITS

      Syntax:
         CLOW  CHIGH
      Description:
         CLOW:   Lower phase speed limit (m/s).
                 CLOW will be computed automatically if you set
                 it to zero. However, by using a nonzero CLOW you
                 can skip the computation of slower modes. Mainly
                 this is used to exclude interfacial modes (e.g.
                 a Scholte wave).  The root finder is especially
                 slow in converging to these interfacial
                 modes and when the source and receiver are
                 sufficiently are far from the interface the
                 interfacial modes are negligible.

         CHIGH:  Upper phase speed limit (m/s).
                 The larger CHIGH is, the more modes are
                 calculated and the longer the execution time.
                 Therefore CHIGH should be set as small as
                 possible to minimize execution time.

                 On the other hand, CHIGH controls the maximum
                 ray angle included in a subsequent field
                 calculation-- ray paths are included which turn
                 at the depth corresponding to CHIGH in the SSP.
                 Thus a larger CHIGH means more deeply
                 penetrating rays are included.

                 Choice of CHIGH then becomes a matter of
                 experience.  In the far-field and at
                 high-frequencies, rays travelling in the ocean
                 bottom are severely attenuated and one may set
                 CHIGH to the sound speed at the ocean bottom. In
                 the near-field, low-frequency case, rays
                 refracted in the bottom may contribute
```

```
                significantly to the field and CHIGH should be
                chosen to include such ray paths.

                KRAKEN will (if necessary) reduce CHIGH so that
                only trapped (non-leaky) modes are computed.

                KRAKENC will attempt to compute leaky modes if
                CHIGH exceeds the phase velocity of either the
                S-wave or P-wave speed in the half-space. Leaky
                mode computations are somewhat experimental at
                this time.


(8) - MAXIMUM RANGE

      Syntax:
         RMAX
      Description:
         RMAX:  Maximum range (km).
                This parameter should be set to the largest
                range for which a field calculation will be
                desired.

                During the mode calculation the mesh is doubled
                successively until the eigenvalues are
                sufficiently accurate at this range. If you set
                it to zero, then no mesh doublings will be
                performed. You don't need to worry too much
                about this parameter-- even if you set it to
                zero the results will usually be reasonable.

(9) - SOURCE/RECEIVER DEPTH INFO

      Syntax:
         NSD
         SD(1:NSD)
         NRD
         RD(1:NRD)

      Description:
         NSD:  The number of source   depths.
         SD(): The source   depths (m).
         NRD:  The number of receiver depths.
         RD(): The receiver depths (m).
```

```
        This data is read in using list-directed I/O so you can
        type it just about any way you want, e.g. on one line or
        split onto several lines.  Also if your depths are
        equally spaced then you can type just the first and last
        depths followed by a '/' and the intermediate depths
        will be generated automatically.

        CPU time is essentially independent of the number of
        sources and receivers so that you can freely ask for up
        to 4095 depths. However, for high-frequencies the
        storage for the mode files can be excessive.

        The source/rcvr depths are sorted and merged and then the
        modes are calculated at the union of the two sets
        of depths. Thus, it doesn't matter if you mix up source
        and receiver depths. Furthermore, you can leave out
        either the source or receiver specification (but not
        both simultaneously) simply by using a '/' for that
        line.

        Sources and receivers cannot be placed in a half-space.

        If you are going to be doing a coupled-mode calculation
        then you must specify a large number of receiver depths
        spanning the entire column (down to the half-space).
        Fine sampling (about 10 points/wavelenght) is needed
        to calculate the coupling integrals accurately.

--------------------------------------------------------------
 SAMPLE PRINT OUT

 The print-out for this deck is shown below



 KRAKEN- FRAMIV Twersky S/S ice scatter
 Frequency =   20.00     NMEDIA =   4


     N2-LINEAR approximation to SSP
     Attenuation units: dB/mkHz
     TWERSKY SOFT BOSS surface scatter model

 Twersky ice model parameters:
 Bumden =    0.920000E-02 Eta =    8.20     Xi =    5.10
```

```
  Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


       ( Number of pts =    750  RMS roughness =  0.000E+00 )
   0.00       1436.00      0.00      1.03       0.0000     0.0000
  30.00       1437.40      0.00      1.03       0.0000     0.0000
  50.00       1437.70      0.00      1.03       0.0000     0.0000
  80.00       1439.50      0.00      1.03       0.0000     0.0000
 100.00       1441.90      0.00      1.03       0.0000     0.0000
 125.00       1444.60      0.00      1.03       0.0000     0.0000
 150.00       1450.00      0.00      1.03       0.0000     0.0000
 175.00       1456.10      0.00      1.03       0.0000     0.0000
 200.00       1458.40      0.00      1.03       0.0000     0.0000
 250.00       1460.00      0.00      1.03       0.0000     0.0000
 300.00       1460.50      0.00      1.03       0.0000     0.0000
 350.00       1460.60      0.00      1.03       0.0000     0.0000
 400.00       1461.00      0.00      1.03       0.0000     0.0000
 450.00       1461.50      0.00      1.03       0.0000     0.0000
 500.00       1462.00      0.00      1.03       0.0000     0.0000
 600.00       1462.90      0.00      1.03       0.0000     0.0000
 700.00       1463.90      0.00      1.03       0.0000     0.0000
 800.00       1464.80      0.00      1.03       0.0000     0.0000
 900.00       1465.80      0.00      1.03       0.0000     0.0000
1000.00       1466.70      0.00      1.03       0.0000     0.0000
1100.00       1467.00      0.00      1.03       0.0000     0.0000
1200.00       1469.00      0.00      1.03       0.0000     0.0000
1300.00       1469.50      0.00      1.03       0.0000     0.0000
1400.00       1471.80      0.00      1.03       0.0000     0.0000
1600.00       1474.50      0.00      1.03       0.0000     0.0000
1800.00       1477.00      0.00      1.03       0.0000     0.0000
2000.00       1479.60      0.00      1.03       0.0000     0.0000
2500.00       1487.90      0.00      1.03       0.0000     0.0000
3750.00       1510.40      0.00      1.03       0.0000     0.0000

       ( Number of pts =     35  RMS roughness =  0.000E+00 )
3750.00       1504.60      0.00      1.50       0.1500     0.0000
3808.33       1603.07      0.00      1.50       0.1500     0.0000

       ( Number of pts =     35  RMS roughness =  0.000E+00 )
3808.33       1603.07      0.00      1.53       0.1500     0.0000
3866.66       1701.53      0.00      1.53       0.1500     0.0000
```

```
         ( Number of pts =    35  RMS roughness =  0.000E+00 )
   3866.66      1701.53      0.00     1.57       0.1500    0.0000
   3925.00      1800.00      0.00     1.57       0.1500    0.0000

    ACOUSTO-ELASTIC half-space,  ( RMS roughness =  0.000E+00 )
   3925.00      1800.00      0.00     1.60       0.1500    0.0000

 CLOW =  0.00000E+00 CHIGH =   1504.0
 RMAX =    300.0000000000000

 Number of sources   =           1
   100.0000

 Number of receivers =           1
   200.0000

 Mesh multiplier   CPU seconds
       1             16.4
       2             15.1

     I          K                ALPHA          PHASE SPEED
     1   0.8625082052E-01  -0.8519020992E-06    1456.956646
     2   0.8582849772E-01  -0.1302695655E-06    1464.125663
     3   0.8562855085E-01  -0.1059327457E-06    1467.544468
     4   0.8545402623E-01  -0.1136748056E-06    1470.541667
     5   0.8527187871E-01  -0.1192384459E-06    1473.682861
     6   0.8510445198E-01  -0.1156165482E-06    1476.582050
     7   0.8495255965E-01  -0.1130917467E-06    1479.222129
     8   0.8479984039E-01  -0.1185453302E-06    1481.886116
     9   0.8465149335E-01  -0.1314814525E-06    1484.483039
    10   0.8450452348E-01  -0.1255743704E-06    1487.064845
    11   0.8435857532E-01  -0.1276318031E-06    1489.637606
    12   0.8421637950E-01  -0.1377681231E-06    1492.152796
    13   0.8407780307E-01  -0.1377169389E-06    1494.612151
    14   0.8393959060E-01  -0.1339925824E-06    1497.073136
    15   0.8380370528E-01  -0.1378254389E-06    1499.500598
    16   0.8367091002E-01  -0.1450063419E-06    1501.880476

--------------------------------------------------------------
```

If the program aborts in some way, examine the print file which is produced. Frequently an expected line has been omitted and the environmental file is therefore misinterpreted.

The message "FAILURE TO CONVERGE IN SECANT" occurs when KRAKEN requires more than 500 iterations to converge to a mode. Usually less than 20 iterations are needed but convergence to interfacial modes (Scholte or Stoneley waves) can be exceptionally slow, especially at higher frequencies. The simplest solution is to exclude interfacial modes by setting the lower phase-speed limit to the minimum p-wave speed in the problem. Alternately, you can increase the value of MAXNIT which controls the MAXimum Number of ITerations in the root finder.

***** Group speed ***** By popular demand, the new versions of KRAKEN and KRAKENC compute group speed using the formula in Ch. 5 of Jensen, Kuperman, Porter, and Schmidt, Computational Ocean Acoustics. Note that this formula is only valide for acoustic problems (with no elasticity). It also does not address the role of interfacial or boundary scatter.

4.3 Acoustic Field Calculations

4.3.1 field.hlp

The FIELD program uses the modes calculated by KRAKEN and produces a shade file which contains a sequence of snapshots of the acoustic field as a function of range and depth. A snapshot is produced for every source depth specified by the user.

```
Files:

        Name           Unit         Description
Input
        *.FLP            5       FieLd Parameters
        *.MOD          30-99     MODe files

Output
        *.PRT            6       PRinT file
        *.SHD           25       SHaDe file

----------------------------------------------------------

EXAMPLE AND DESCRIPTION OF FLP FILE:

/,                                ! TITLE
'RA'                              ! OPT 'X/R', 'C/A'
9999                              ! M  (number of modes to include)
1                                 ! NPROF
0.0                               ! RPROF(1:NPROF) (km)
501                               ! NR
200.0  220.0 /                    ! R(1:NR)   (km)
1                                 ! NSD
500.0 /                           ! SD(1:NSD)   (m)
1                                 ! NRD
2500.0 /                          ! RD(1:NRD)   (m)
1                                 ! NRR
0.0 /                             ! RR(1:NRR)   (m)


 (1) - TITLE

       Syntax:
          TITLE
       Description:
          TITLE: Title to be written to the shade file.
                 If you type a /, the title is taken from the
```

```
              first mode file.

(2) - OPTIONS

      Syntax:
         OPTION
      Description:
         OPTION(1:1): Source type.
                      'R' point source
                          (cylindrical (R-Z) coordinates)
                      'X' line  source
                          (cartesian   (X-Z) coordinates)
         OPTION(2:2): Selects coupled or adiabatic mode theory.
                      'C' Coupled mode theory.
                      'A' Adiabatic mode theory (default).
         OPTION(4:4): Selects coherent or incoherent mode addition
                      'C' Coherent
                      'I' Incoherent

         For a coupled mode run you ***must*** be sure that the
         modes are finely sampled throughout the media
         (excluding the halfspaces if present) so that FIELD can accurately
         calculate the coupling integrals. This is done by using
         a large number of receiver depths (NRD) when you
         do the KRAKEN run. This number should be set to
         give about 10 points/wavelength.


(3) - NUMBER OF MODES
      Syntax:
         M
      Description:
         M:     Number of modes to use in the field computation.
                If the number of modes specified exceeds the
                number computed then the program uses all the
                computed modes.


(4) - PROFILE RANGES

      Syntax:
         NPROF  RPROF(1:NPROF)
      Description:
         NPROF:    The number of profiles, i.e. ranges where a new
                   set of modes is to be used.
```

```
   RPROF(): Ranges (km) of each of these profiles.
            For a range independent problem there is only
            one profile and its range is arbitrary.
            mode files must exist for each range of a
            new profile and be assigned in sequence to
            units 30,31,... The modes for the last SSP
            profile are extended in a range-independent
            fashion to infinity so that RMAX can exceed
            RPROF(NPROF).
            *** NOTE: RPROF( 1 ) must be 0.0 ***



(6) - SOURCE/RECEIVER LOCATIONS

      Syntax:
         NR
         R(1:NR)
         NSD
         SD(1:NSD)
         NRD
         RD(1:NRD)
         NRR
         RR(1:NRR)

      Description:
         NR:   Number of receiver ranges.
         R():  The receiver ranges (km)
         NSD:  The number of source depths.
         SD(): The source depths (m).
         NRD:  The number of receiver depths.
         RD(): The receiver depths (m).
         NRR:  The number of receiver range-displacements.
               Must equal NRD. (YES, IT IS REDUNDANT)
         RR(): The receiver displacements (m).
               This vector should be all zeros for a perfectly
               vertical array.

               The  field is computed by stepping through the
               ranges, R(1:NR), and adding in the range
               displacements, RR() before computing the field
               on the array. Nonzero values are used to tilt or
               distort the receiving array, thereby simulating the
               distortion which occurs on an array deployed in
               the ocean.
```

```
The format of the source/rcvr info is an integer
indicating the number of sources (receivers) followed by
real numbers indicating the depth (range) of each
receiver.  Since this data is read in using list-directed
I/O you can type it just about any way you want, e.g. on
one line or split onto several lines.  Also if your depths
are equally spaced then you can type just the first and
last depths followed by a '/' and the intermediate depths
will be generated automatically.
```

Chapter 5

Test Problems

The following test problems have been developed to validate the model by exercising various components of the code and to illustrate the input structure required for various kinds of scenarios. In brief, we have:

- PEKERIS: A simple (two-layer) Pekeris waveguide.
- TWERSKY: The Pekeris wave guide with surface roughness. Demonstrates that the Twersky scatter works properly.
- SCHOLTE: A two-layer waveguide with an elastic bottom which leads to a Scholte wave. Demonstrates that the elastic half-space condition functions correctly.
- DOUBLE: A double-duct problem demonstrating that gradients are handled properly.
- FLUSED: A three-layer problem involving ocean, sediment and half-space. Demonstrates that multiple layers are treated properly.
- ELSED: A three-layer problem with shear properties in the sediment. Demonstrates that elastic media are handled properly.
- ATTEN: A two-layer problem with volume attenuation. Demonstrates that attenuation is handled properly.
- NORMAL: A problem with several density changes to check out the modal normalization in a severe case.
- ICE: A problem with an elastic ice layer to demonstrate that elastic layers above the water column are handled properly.

For each of these cases, we provide the environmental file along with the print-out from KRAKEN. The CPU times printed were obtained on a 0.5 megaflop workstation.

In all cases, the frequency is chosen as 10 Hz and the transmission loss is computed for a source/receiver depth combination of 500 m and 2500 m respectively. The transmission loss plots show an overlay of KRAKEN (solid line), KRAKENC (dotted line) and SCOOTER (dashed line) results. These results have also been checked against the NRL FSTFLD code which agrees to within 1 dB (usually less).

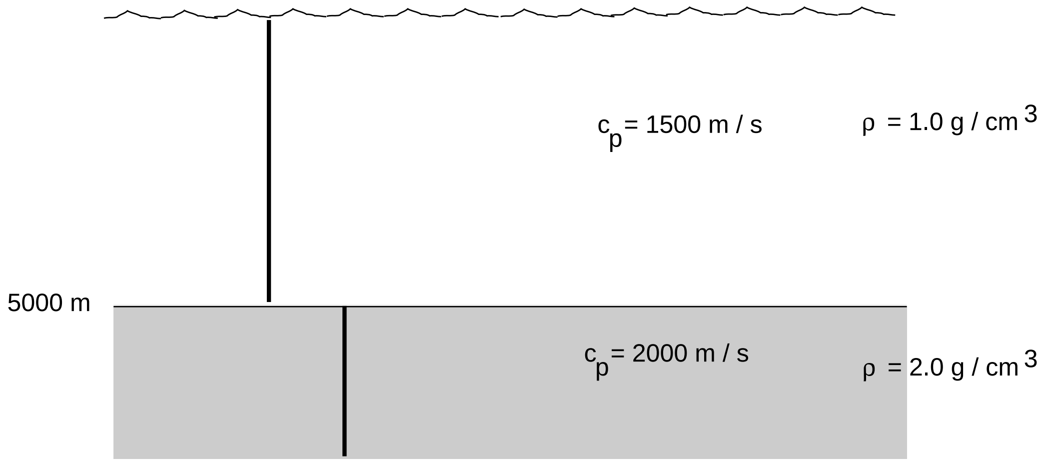

Figure 5.1: Schematic of the PEKERIS problem.

5.1 PEKERIS

This problem involves a homogeneous fluid layer with a sound speed of 1500 m/s overlying a faster bottom with sound speed 2000 m/s and density of 2.0 g/cm^3.

```
'Pekeris problem'
10.0
1
'NVF'
500  0.0  5000.0
     0.0  1500.0 /
  5000.0  1500.0 /
'A'  0.0
  5000.0  2000.0  0.0  2.0 /
1400.0  2000.0
1000.0                   ! RMAX (km)
1  500.0 /               ! NSD  SD(1:NSD)
1 2500.0 /               ! NRD  RD(1:NRD)
```

```
KRAKEN- Pekeris problem
Frequency =   10.00     NMEDIA =   1


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI



        ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00     1.00       0.0000    0.0000
  5000.00      1500.00      0.00     1.00       0.0000    0.0000

                                ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      2000.00      0.00     2.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =           1
  500.0000

Number of receivers =           1
  2500.000

Mesh multiplier   CPU seconds
       1             5.49
       2             6.21

   I          K                 ALPHA          PHASE SPEED
   1    0.4188332253E-01   0.0000000000E+00    1500.164010
   2    0.4186958032E-01   0.0000000000E+00    1500.656385
   3    0.4184666447E-01   0.0000000000E+00    1501.478167
   4    0.4181455674E-01   0.0000000000E+00    1502.631092
   5    0.4177323161E-01   0.0000000000E+00    1504.117605
   6    0.4172265636E-01   0.0000000000E+00    1505.940862
   7    0.4166279103E-01   0.0000000000E+00    1508.104751
   8    0.4159358848E-01   0.0000000000E+00    1510.613904
   9    0.4151499439E-01   0.0000000000E+00    1513.473722
  10    0.4142694720E-01   0.0000000000E+00    1516.690399
  11    0.4132937809E-01   0.0000000000E+00    1520.270954
```

12	0.4122221089E-01	0.0000000000E+00	1524.223270
13	0.4110536194E-01	0.0000000000E+00	1528.556132
14	0.4097873993E-01	0.0000000000E+00	1533.279285
15	0.4084224568E-01	0.0000000000E+00	1538.403485
16	0.4069577186E-01	0.0000000000E+00	1543.940567
17	0.4053920272E-01	0.0000000000E+00	1549.903522
18	0.4037241363E-01	0.0000000000E+00	1556.306582
19	0.4019527072E-01	0.0000000000E+00	1563.165317
20	0.4000763035E-01	0.0000000000E+00	1570.496741
21	0.3980933859E-01	0.0000000000E+00	1578.319442
22	0.3960023053E-01	0.0000000000E+00	1586.653720
23	0.3938012967E-01	0.0000000000E+00	1595.521741
24	0.3914884708E-01	0.0000000000E+00	1604.947725
25	0.3890618058E-01	0.0000000000E+00	1614.958141
26	0.3865191380E-01	0.0000000000E+00	1625.581942
27	0.3838581509E-01	0.0000000000E+00	1636.850824
28	0.3810763645E-01	0.0000000000E+00	1648.799530
29	0.3781711221E-01	0.0000000000E+00	1661.466183
30	0.3751395766E-01	0.0000000000E+00	1674.892680
31	0.3719786754E-01	0.0000000000E+00	1689.125136
32	0.3686851438E-01	0.0000000000E+00	1704.214399
33	0.3652554677E-01	0.0000000000E+00	1720.216633
34	0.3616858743E-01	0.0000000000E+00	1737.194000
35	0.3579723130E-01	0.0000000000E+00	1755.215440
36	0.3541104368E-01	0.0000000000E+00	1774.357560
37	0.3500955866E-01	0.0000000000E+00	1794.705659
38	0.3459227830E-01	0.0000000000E+00	1816.354868
39	0.3415867360E-01	0.0000000000E+00	1839.411384
40	0.3370818983E-01	0.0000000000E+00	1863.993688
41	0.3324026217E-01	0.0000000000E+00	1890.233379
42	0.3275436107E-01	0.0000000000E+00	1918.274423
43	0.3225014368E-01	0.0000000000E+00	1948.265834
44	0.3172824619E-01	0.0000000000E+00	1980.312832

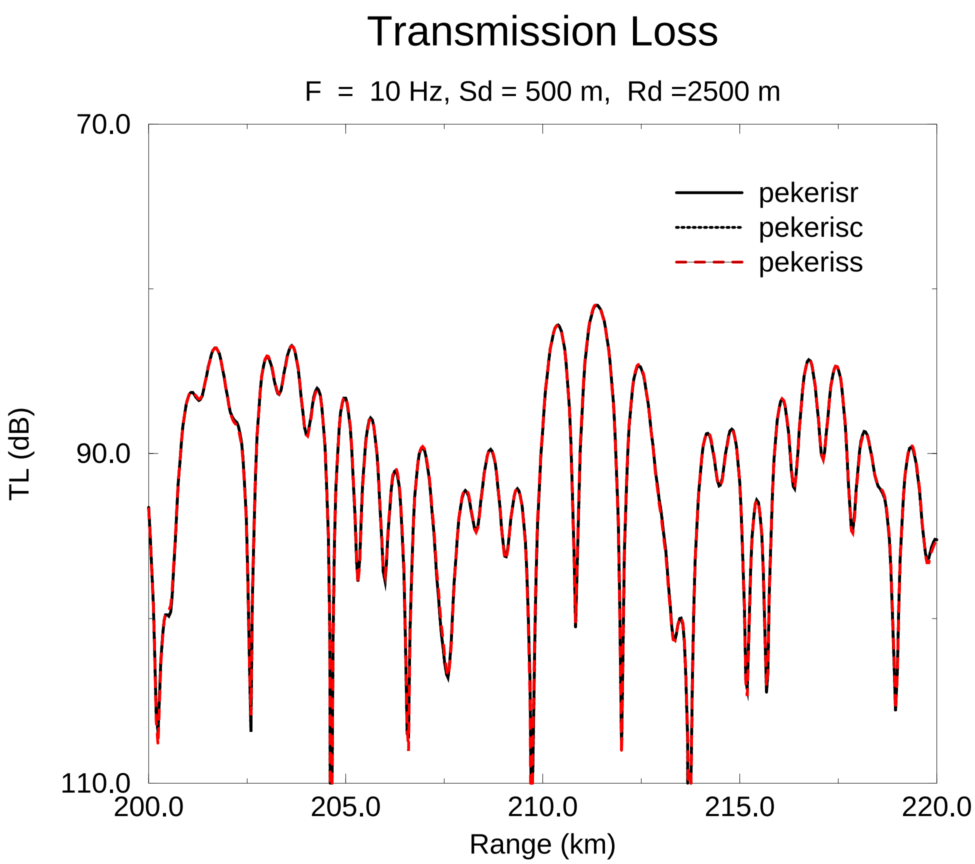

Figure 5.2: Transmission loss for the PEKERIS problem.

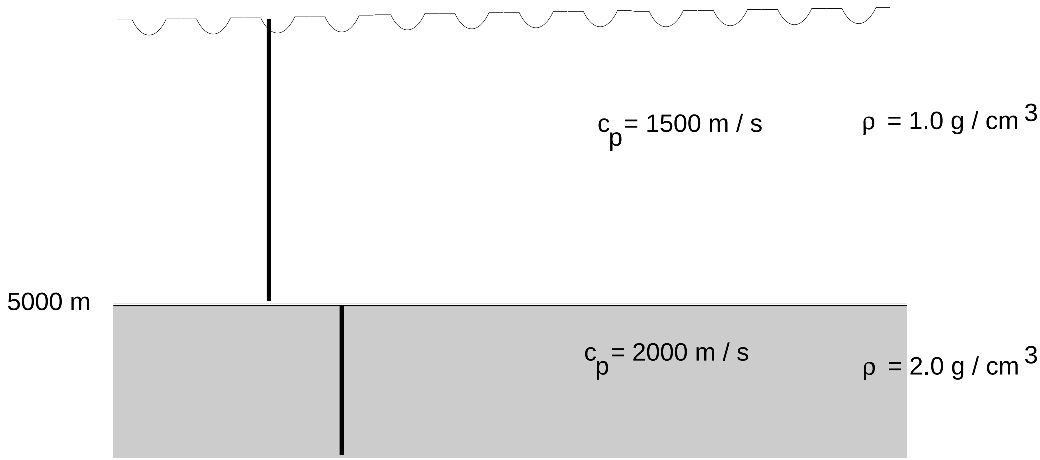

Figure 5.3: Schematic of the TWERSKY problem.

5.2 TWERSKY

The previous Pekeris problem is modified by the inclusion of surface scatter. The rough surface involves a density of 0.092 bosses per km of width 8.2 m and height 5.1 m. Note that the KRAKEN result differs from the KRAKENC and SCOOTER results. This reflects the error in using a perturbation theory which however is probably negligible considering the approximations of the scatter model.

```
'Pekeris problem with Twersky ice scatter'
10.0
1
'NSF'
0.092  8.2  5.1
500 0.0 5000.0
    0.0 1500.0 /
 5000.0  1500.0 /
'A'  0.0
 5000.0  2000.0    0.0  2.0  0.0  0.0
1400.0  2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Pekeris problem with Twersky ice scatter
Frequency =   10.00     NMEDIA =   1


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    Twersky SOFT BOSS scatter model

Twersky ice model parameters:
Bumden =    0.920000E-01  Eta =    8.20      Xi =    5.10



     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00     1.00       0.0000    0.0000
  5000.00      1500.00      0.00     1.00       0.0000    0.0000

                                   ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      2000.00      0.00     2.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             8.08
       2             6.19

   I           K                 ALPHA          PHASE SPEED
   1   0.4188333967E-01  -0.7143639068E-09    1500.163396
   2   0.4186964892E-01  -0.2858563396E-08    1500.653927
   3   0.4184681891E-01  -0.6435953313E-08    1501.472626
   4   0.4181483151E-01  -0.1145206277E-07    1502.621218
   5   0.4177366141E-01  -0.1791463612E-07    1504.102129
   6   0.4172327607E-01  -0.2583358102E-07    1505.918494
```

7	0.4166363582E-01	-0.3522095285E-07	1508.074172
8	0.4159469382E-01	-0.4609093903E-07	1510.573761
9	0.4151639611E-01	-0.5845985229E-07	1513.422622
10	0.4142868154E-01	-0.7234613786E-07	1516.626905
11	0.4133148173E-01	-0.8777040005E-07	1520.193577
12	0.4122472102E-01	-0.1047554344E-06	1524.130462
13	0.4110831629E-01	-0.1233263186E-06	1528.446279
14	0.4098217683E-01	-0.1435104786E-06	1533.150699
15	0.4084620412E-01	-0.1653378169E-06	1538.254396
16	0.4070029155E-01	-0.1888408516E-06	1543.769115
17	0.4054432412E-01	-0.2140548873E-06	1549.707744
18	0.4037817804E-01	-0.2410182110E-06	1556.084403
19	0.4020172036E-01	-0.2697723168E-06	1562.914535
20	0.4001480842E-01	-0.3003621806E-06	1570.215017
21	0.3981728933E-01	-0.3328365176E-06	1578.004282
22	0.3960899938E-01	-0.3672481421E-06	1586.302458
23	0.3938976329E-01	-0.4036543176E-06	1595.131522
24	0.3915939350E-01	-0.4421171667E-06	1604.515480
25	0.3891768932E-01	-0.4827041259E-06	1614.480566
26	0.3866443598E-01	-0.5254884517E-06	1625.055467
27	0.3839940360E-01	-0.5705497741E-06	1636.271587
28	0.3812234607E-01	-0.6179747460E-06	1648.163336
29	0.3783299981E-01	-0.6678576894E-06	1660.768466
30	0.3753108238E-01	-0.7203013712E-06	1674.128458
31	0.3721629100E-01	-0.7754178193E-06	1688.288956
32	0.3688830091E-01	-0.8333291792E-06	1703.300275
33	0.3654676364E-01	-0.8941686039E-06	1719.217978
34	0.3619130513E-01	-0.9580810818E-06	1736.103543
35	0.3582152384E-01	-0.1025224135E-05	1754.025132
36	0.3543698884E-01	-0.1095768032E-05	1773.058466
37	0.3503723827E-01	-0.1169895081E-05	1793.287833
38	0.3462177842E-01	-0.1247796785E-05	1814.807209
39	0.3419008460E-01	-0.1329666243E-05	1837.721486
40	0.3374160587E-01	-0.1415679057E-05	1862.147680
41	0.3327577965E-01	-0.1505943298E-05	1888.215805
42	0.3279207350E-01	-0.1600349816E-05	1916.068317
43	0.3229012280E-01	-0.1697989094E-05	1945.853643
44	0.3177042607E-01	-0.1793021126E-05	1977.683678

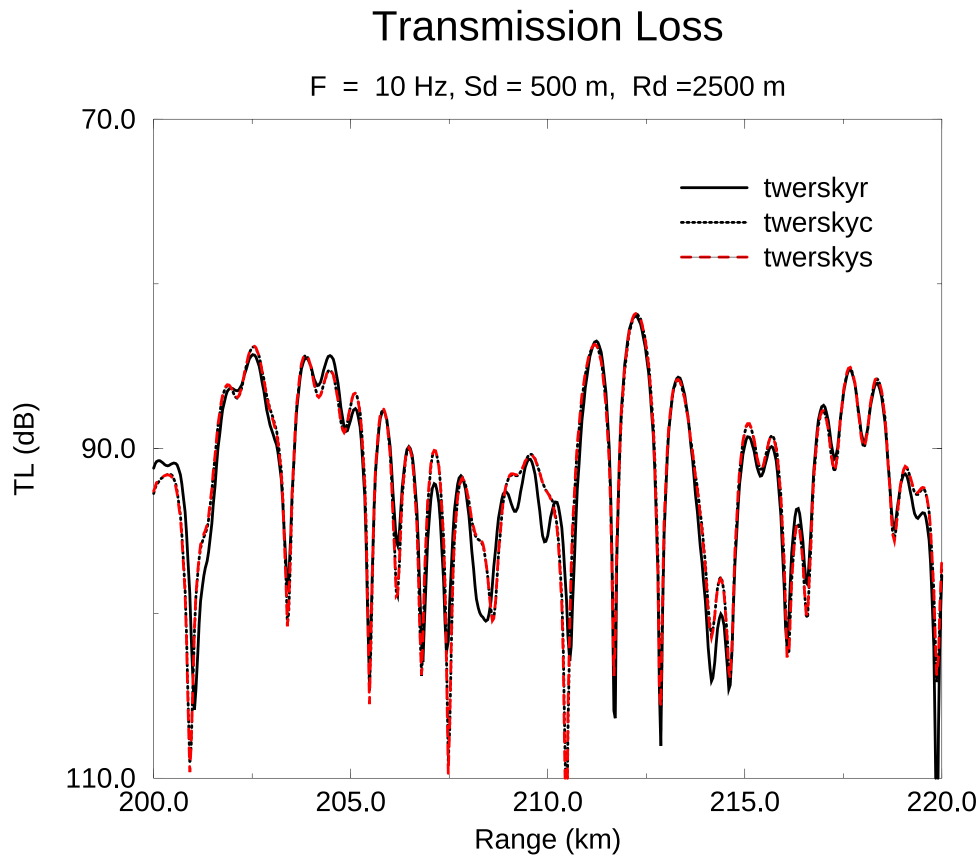

Figure 5.4: Transmission loss for the TWERSKY problem.

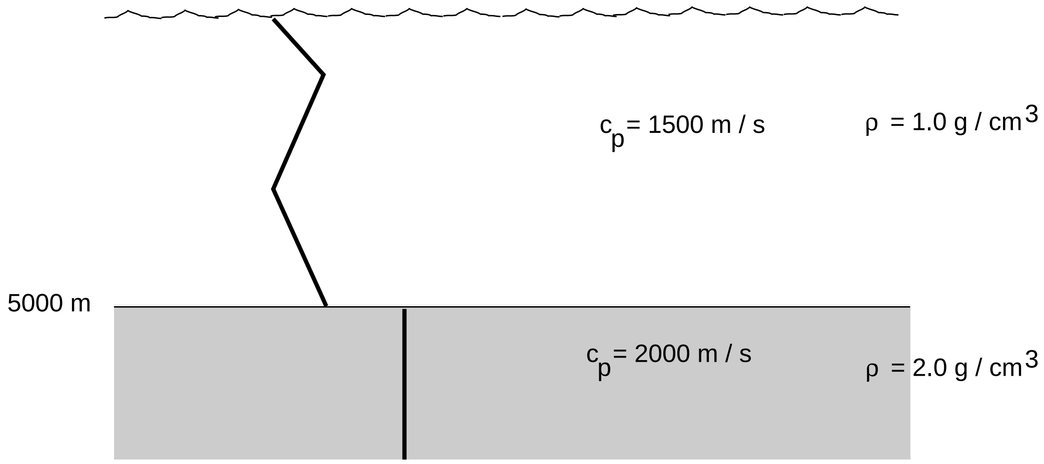

Figure 5.5: Schematic of the DOUBLE problem.

5.3 DOUBLE

The ocean profile is converted to one involving three piecewise linear segments defining a double-duct profile.

```
'Double-duct problem'
10.0
3
'NVF'
100 0.0 1000.0
    0.0 1500.0 /
 1000.0 1550.0 /
200 0.0 3000.0
 1000.0 1550.0 /
 3000.0 1500.0 /
200 0.0 5000.0
 3000.0 1500.0 /
 5000.0 1550.0 /
'A' 0.0
 5000.0 2000.0   0.0 2.0 0.0 0.0
1400.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Double-duct problem
Frequency =   10.00     NMEDIA =   3


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z           ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =   100  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00      1.00       0.0000    0.0000
  1000.00      1550.00      0.00      1.00       0.0000    0.0000

         ( Number of pts =   200  RMS roughness =  0.000E+00 )
  1000.00      1550.00      0.00      1.00       0.0000    0.0000
  3000.00      1500.00      0.00      1.00       0.0000    0.0000

         ( Number of pts =   200  RMS roughness =  0.000E+00 )
  3000.00      1500.00      0.00      1.00       0.0000    0.0000
  5000.00      1550.00      0.00      1.00       0.0000    0.0000

                                  ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      2000.00      0.00      2.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             5.60
       2             6.18

   I           K                ALPHA          PHASE SPEED
   1   0.4171018652E-01   0.0000000000E+00    1506.391084
   2   0.4147891740E-01   0.0000000000E+00    1514.790091
   3   0.4131862874E-01   0.0000000000E+00    1520.666464
```

4	0.4123681174E-01	0.0000000000E+00	1523.683583
5	0.4117017415E-01	0.0000000000E+00	1526.149801
6	0.4104029641E-01	0.0000000000E+00	1530.979515
7	0.4091561041E-01	0.0000000000E+00	1535.645013
8	0.4080128302E-01	0.0000000000E+00	1539.947973
9	0.4074949725E-01	0.0000000000E+00	1541.904988
10	0.4068324597E-01	0.0000000000E+00	1544.415928
11	0.4057281144E-01	0.0000000000E+00	1548.619650
12	0.4046123964E-01	0.0000000000E+00	1552.889967
13	0.4035440690E-01	0.0000000000E+00	1557.001029
14	0.4024224926E-01	0.0000000000E+00	1561.340487
15	0.4011172669E-01	0.0000000000E+00	1566.421051
16	0.3996592323E-01	0.0000000000E+00	1572.135660
17	0.3980769235E-01	0.0000000000E+00	1578.384713
18	0.3964207800E-01	0.0000000000E+00	1584.978796
19	0.3946677171E-01	0.0000000000E+00	1592.019067
20	0.3927946746E-01	0.0000000000E+00	1599.610614
21	0.3907987820E-01	0.0000000000E+00	1607.780166
22	0.3886748929E-01	0.0000000000E+00	1616.565778
23	0.3864545686E-01	0.0000000000E+00	1625.853546
24	0.3841222010E-01	0.0000000000E+00	1635.725634
25	0.3816711818E-01	0.0000000000E+00	1646.229951
26	0.3790948500E-01	0.0000000000E+00	1657.417743
27	0.3763853318E-01	0.0000000000E+00	1669.349142
28	0.3735627690E-01	0.0000000000E+00	1681.962398
29	0.3706135033E-01	0.0000000000E+00	1695.347107
30	0.3675356291E-01	0.0000000000E+00	1709.544548
31	0.3643204686E-01	0.0000000000E+00	1724.631430
32	0.3609604877E-01	0.0000000000E+00	1740.685067
33	0.3574683553E-01	0.0000000000E+00	1757.689937
34	0.3538311960E-01	0.0000000000E+00	1775.757869
35	0.3500480248E-01	0.0000000000E+00	1794.949511
36	0.3461083089E-01	0.0000000000E+00	1815.381239
37	0.3420046728E-01	0.0000000000E+00	1837.163585
38	0.3377442369E-01	0.0000000000E+00	1860.338274
39	0.3333144286E-01	0.0000000000E+00	1885.062502
40	0.3287145204E-01	0.0000000000E+00	1911.441362
41	0.3239342265E-01	0.0000000000E+00	1939.648482
42	0.3189739326E-01	0.0000000000E+00	1969.811532

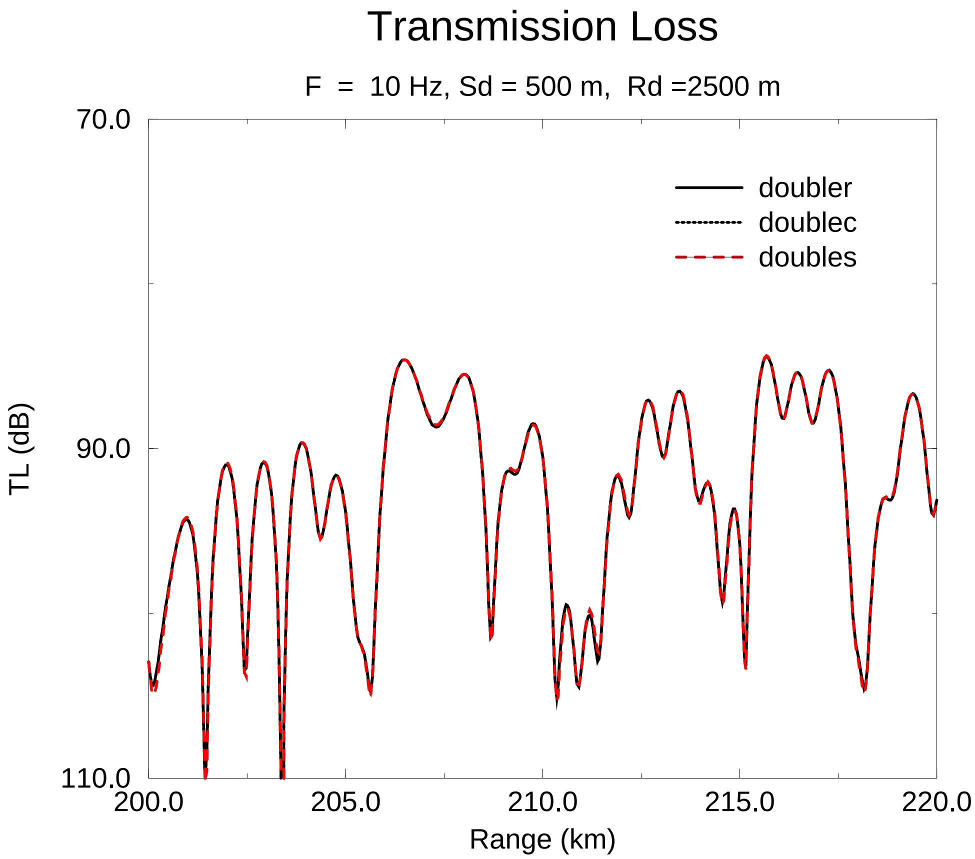

Figure 5.6: Transmission loss for the DOUBLE problem.

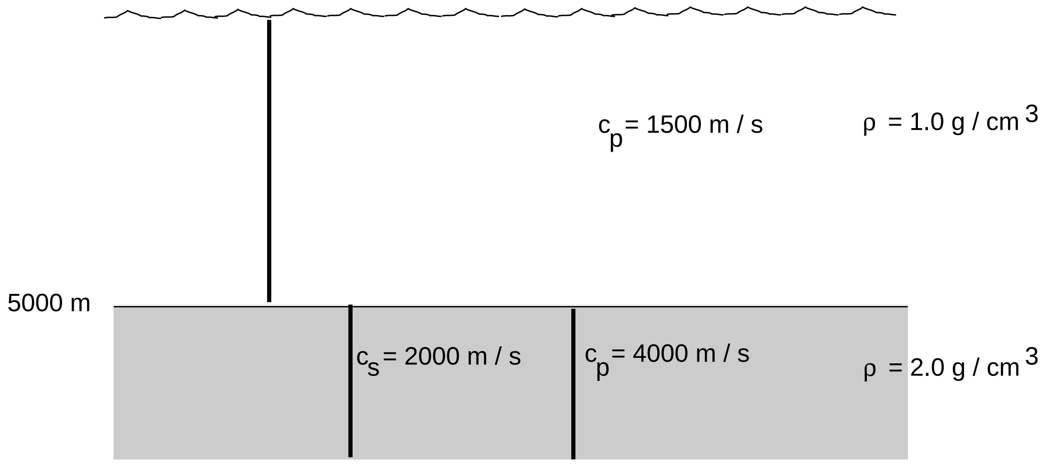

Figure 5.7: Schematic of the SCHOLTE problem.

5.4 SCHOLTE

This problem is a version of the Pekeris waveguide but with an elastic half-space as the bottom. This type of problem has a Scholte mode with a phase velocity less than the slowest speed in the problem. (Since the source and receiver are many wavelenghts from the interface the Scholte mode is not actually important for the transmission loss calculation.)

```
'Scholte waveguide'
10.0
1
'NVM'
500 0.0 5000.0
   0.0 1500.0 /
5000.0 1500.0 /
'A' 0.0
5000.0 4000.0 2000.0 2.0 /
1400.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Scholte waveguide
Frequency =   10.00     NMEDIA =   1


    N2-LINEAR approximation to SSP
    Attenuation units: dB/m
    VACUUM


     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


        ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00     1.00       0.0000    0.0000
  5000.00      1500.00      0.00     1.00       0.0000    0.0000

                                ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      4000.00   2000.00     2.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =           1
  500.0000

Number of receivers =           1
  2500.000

Mesh multiplier   CPU seconds
       1             5.61
       2             6.51
       4             4.64

   I          K                 ALPHA          PHASE SPEED
   1   0.4400982929E-01   0.0000000000E+00    1427.677728
   2   0.4188306870E-01   0.0000000000E+00    1500.173101
   3   0.4186856672E-01   0.0000000000E+00    1500.692715
   4   0.4184439022E-01   0.0000000000E+00    1501.559773
   5   0.4181052921E-01   0.0000000000E+00    1502.775838
   6   0.4176696933E-01   0.0000000000E+00    1504.343123
   7   0.4171369148E-01   0.0000000000E+00    1506.264510
   8   0.4165067147E-01   0.0000000000E+00    1508.543581
   9   0.4157787955E-01   0.0000000000E+00    1511.184643
  10   0.4149527997E-01   0.0000000000E+00    1514.192774
```

11	0.4140283053E-01	0.0000000000E+00	1517.573853
12	0.4130048217E-01	0.0000000000E+00	1521.334613
13	0.4118817854E-01	0.0000000000E+00	1525.482682
14	0.4106585562E-01	0.0000000000E+00	1530.026639
15	0.4093344142E-01	0.0000000000E+00	1534.976071
16	0.4079085559E-01	0.0000000000E+00	1540.341632
17	0.4063800914E-01	0.0000000000E+00	1546.135118
18	0.4047480418E-01	0.0000000000E+00	1552.369538
19	0.4030113364E-01	0.0000000000E+00	1559.059197
20	0.4011688100E-01	0.0000000000E+00	1566.219793
21	0.3992192010E-01	0.0000000000E+00	1573.868514
22	0.3971611492E-01	0.0000000000E+00	1582.024153
23	0.3949931943E-01	0.0000000000E+00	1590.707232
24	0.3927137754E-01	0.0000000000E+00	1599.940135
25	0.3903212305E-01	0.0000000000E+00	1609.747258
26	0.3878137986E-01	0.0000000000E+00	1620.155170
27	0.3851896232E-01	0.0000000000E+00	1631.192776
28	0.3824467597E-01	0.0000000000E+00	1642.891500
29	0.3795831866E-01	0.0000000000E+00	1655.285463
30	0.3765968244E-01	0.0000000000E+00	1668.411654
31	0.3734855636E-01	0.0000000000E+00	1682.310086
32	0.3702473075E-01	0.0000000000E+00	1697.023903
33	0.3668800348E-01	0.0000000000E+00	1712.599409
34	0.3633818906E-01	0.0000000000E+00	1729.085975
35	0.3597513167E-01	0.0000000000E+00	1746.535736
36	0.3559872314E-01	0.0000000000E+00	1765.002998
37	0.3520892659E-01	0.0000000000E+00	1784.543272
38	0.3480580404E-01	0.0000000000E+00	1805.211941
39	0.3438954040E-01	0.0000000000E+00	1827.062890
40	0.3396044231E-01	0.0000000000E+00	1850.148255
41	0.3351886824E-01	0.0000000000E+00	1874.521915
42	0.3306503451E-01	0.0000000000E+00	1900.250643
43	0.3259872074E-01	0.0000000000E+00	1927.433091
44	0.3211925126E-01	0.0000000000E+00	1956.205410
45	0.3162787575E-01	0.0000000000E+00	1986.597316

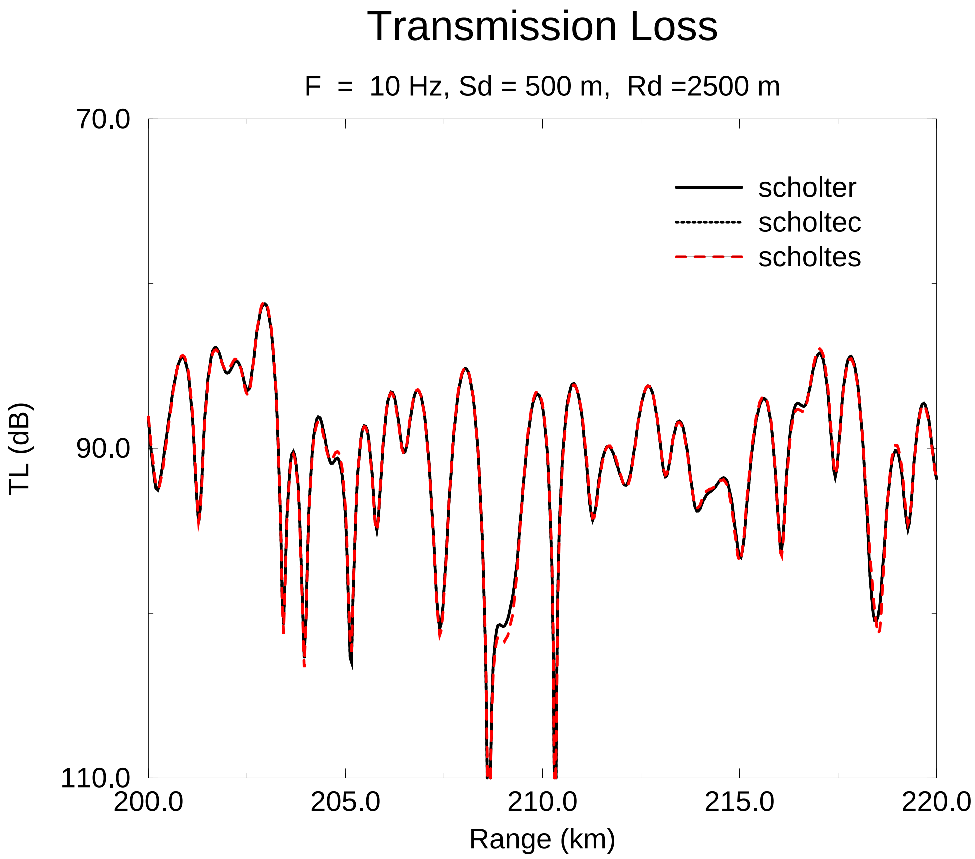

Figure 5.8: Transmission loss for the SCHOLTE problem.

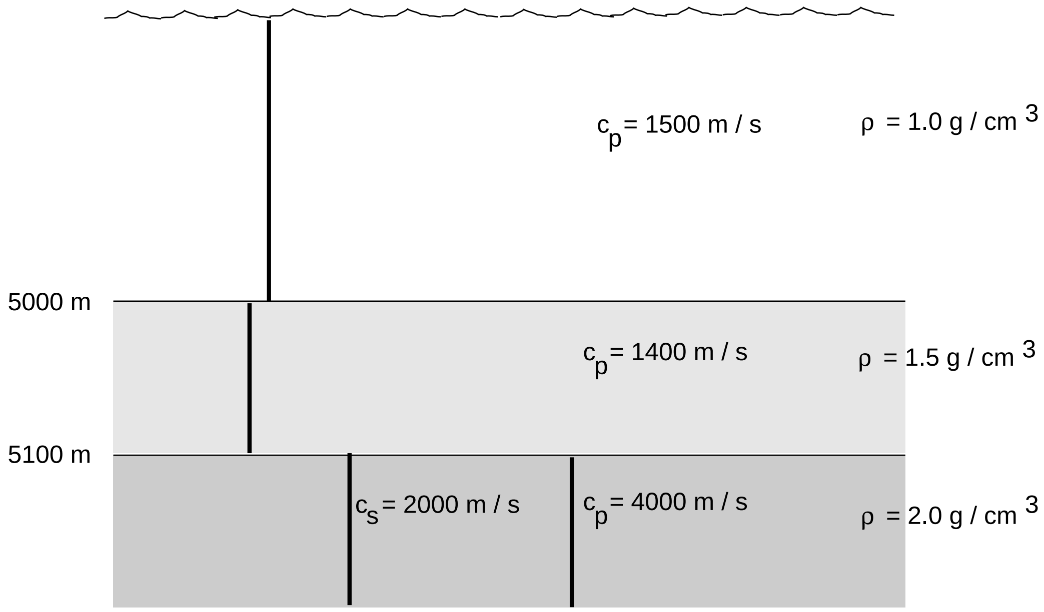

Figure 5.9: Schematic of the FLUSED problem.

5.5 FLUSED

A fluid sediment is inserted between the bottom half-space and the ocean.

```
'Fluid sediment problem'
10.0
2
'NVF'
500 0.0 5000.0
    0.0 1500.0 /
 5000.0 1500.0 /
200 0.0 5100.0
 5000.0 1400.0    0.0 1.5 /
 5100.0 1400.0    0.0 1.5 /
'A' 0.0
 5100.0 4000.0 2000.0 2.0 /
1300.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Fluid sediment problem
Frequency =   10.00     NMEDIA =   2


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z           ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00      1.00       0.0000    0.0000
  5000.00      1500.00      0.00      1.00       0.0000    0.0000

         ( Number of pts =   200  RMS roughness =  0.000E+00 )
  5000.00      1400.00      0.00      1.50       0.0000    0.0000
  5100.00      1400.00      0.00      1.50       0.0000    0.0000

                                  ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5100.00      4000.00   2000.00      2.00       0.0000    0.0000

CLOW =   1300.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             7.96
       2             9.19

   I           K                  ALPHA           PHASE SPEED
   1   0.4762029270E-01   0.0000000000E+00    1319.434416
   2   0.4188346068E-01   0.0000000000E+00    1500.159062
   3   0.4187012980E-01   0.0000000000E+00    1500.636692
   4   0.4184788935E-01   0.0000000000E+00    1501.434219
   5   0.4181670690E-01   0.0000000000E+00    1502.553829
   6   0.4177653892E-01   0.0000000000E+00    1503.998529
   7   0.4172733229E-01   0.0000000000E+00    1505.772107
```

8	0.4166902579E-01	0.0000000000E+00	1507.879099
9	0.4160155146E-01	0.0000000000E+00	1510.324756
10	0.4152483561E-01	0.0000000000E+00	1513.115035
11	0.4143879961E-01	0.0000000000E+00	1516.256592
12	0.4134336028E-01	0.0000000000E+00	1519.756804
13	0.4123843013E-01	0.0000000000E+00	1523.623787
14	0.4112391725E-01	0.0000000000E+00	1527.866441
15	0.4099972515E-01	0.0000000000E+00	1532.494495
16	0.4086575247E-01	0.0000000000E+00	1537.518565
17	0.4072189255E-01	0.0000000000E+00	1542.950220
18	0.4056803308E-01	0.0000000000E+00	1548.802057
19	0.4040405563E-01	0.0000000000E+00	1555.087778
20	0.4022983521E-01	0.0000000000E+00	1561.822283
21	0.4004523991E-01	0.0000000000E+00	1569.021767
22	0.3985013046E-01	0.0000000000E+00	1576.703824
23	0.3964435995E-01	0.0000000000E+00	1584.887564
24	0.3942777350E-01	0.0000000000E+00	1593.593741
25	0.3920020817E-01	0.0000000000E+00	1602.844883
26	0.3896149284E-01	0.0000000000E+00	1612.665442
27	0.3871144846E-01	0.0000000000E+00	1623.081945
28	0.3844988844E-01	0.0000000000E+00	1634.123157
29	0.3817661955E-01	0.0000000000E+00	1645.820238
30	0.3789144340E-01	0.0000000000E+00	1658.206904
31	0.3759415875E-01	0.0000000000E+00	1671.319565
32	0.3728456516E-01	0.0000000000E+00	1685.197422
33	0.3696246847E-01	0.0000000000E+00	1699.882494
34	0.3662768905E-01	0.0000000000E+00	1715.419528
35	0.3628007398E-01	0.0000000000E+00	1731.855704
36	0.3591951486E-01	0.0000000000E+00	1749.240025
37	0.3554597307E-01	0.0000000000E+00	1767.622255
38	0.3515951389E-01	0.0000000000E+00	1787.051245
39	0.3476034709E-01	0.0000000000E+00	1807.572661
40	0.3434886085E-01	0.0000000000E+00	1829.226691
41	0.3392560858E-01	0.0000000000E+00	1852.047928
42	0.3349116237E-01	0.0000000000E+00	1876.072630
43	0.3304572812E-01	0.0000000000E+00	1901.360831
44	0.3258859668E-01	0.0000000000E+00	1928.031872
45	0.3211808726E-01	0.0000000000E+00	1956.276305
46	0.3163418448E-01	0.0000000000E+00	1986.201133

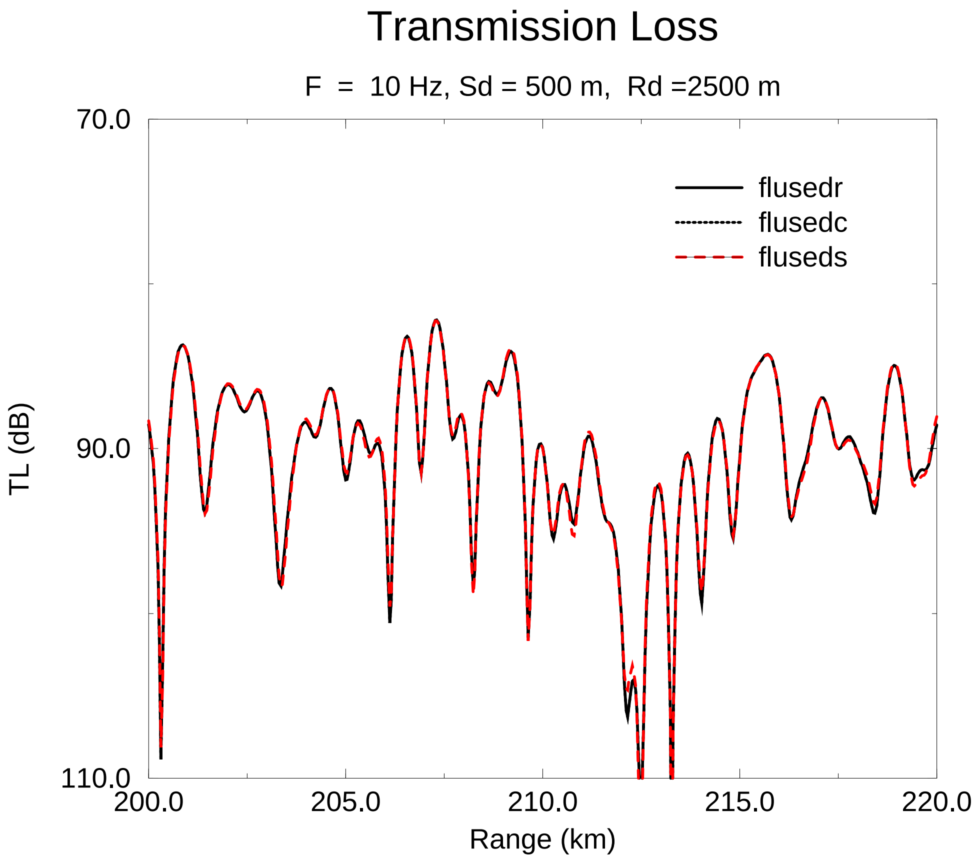

Figure 5.10: Transmission loss for the FLUSED problem.

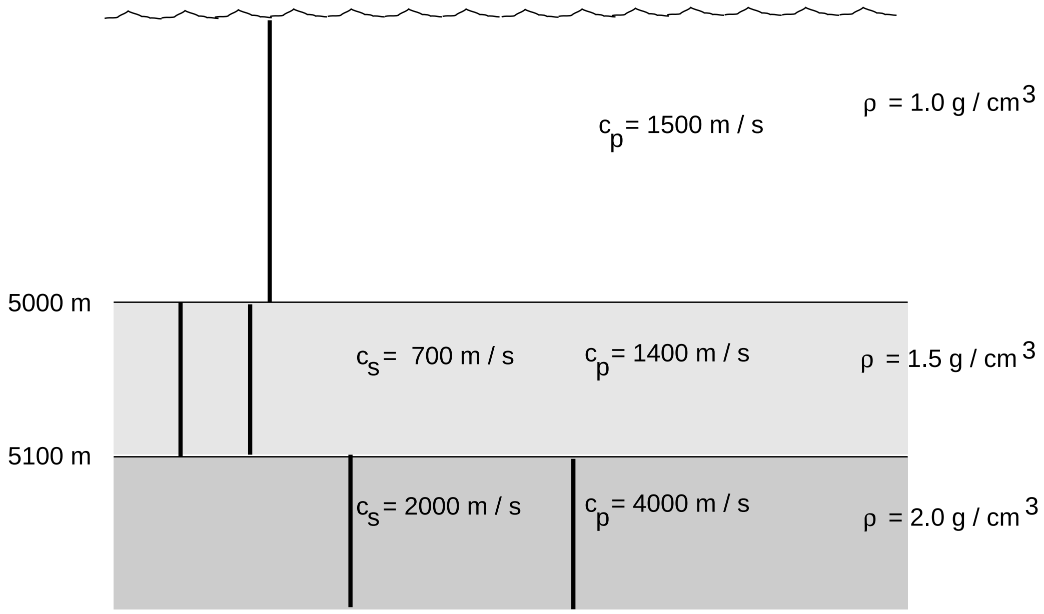

Figure 5.11: Schematic of the ELSED problem.

5.6 ELSED

The previous problem (FLUSED) is modified by including shear properties in the sediment. This problem has several interfacial modes with phase velocities below 1300 m/s which have been excluded from the calculation.

```
'Elastic sediment problem'
10.0
2
'NVF'
500 0.0 5000.0
    0.0 1500.0 /
 5000.0 1500.0 /
200 0.0 5100.0
 5000.0 1400.0  700.0 1.5 /
 5100.0 1400.0  700.0 1.5 /
'A' 0.0
 5100.0 4000.0 2000.0 2.0 /
1300.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Elastic sediment problem
Frequency =   10.00     NMEDIA =   2


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00       1500.00      0.00      1.00       0.0000    0.0000
  5000.00       1500.00      0.00      1.00       0.0000    0.0000

         ( Number of pts =   200  RMS roughness =  0.000E+00 )
  5000.00       1400.00    700.00      1.50       0.0000    0.0000
  5100.00       1400.00    700.00      1.50       0.0000    0.0000

                                  ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5100.00       4000.00   2000.00      2.00       0.0000    0.0000

CLOW =   1300.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             23.9
       2             38.2

   I           K                 ALPHA          PHASE SPEED
   1    0.4271788618E-01   0.0000000000E+00    1470.855857
   2    0.4188323798E-01   0.0000000000E+00    1500.167038
   3    0.4186924441E-01   0.0000000000E+00    1500.668425
   4    0.4184591718E-01   0.0000000000E+00    1501.504981
   5    0.4181324891E-01   0.0000000000E+00    1502.678091
   6    0.4177122866E-01   0.0000000000E+00    1504.189728
   7    0.4171984138E-01   0.0000000000E+00    1506.042473
```

8	0.4165906753E-01	0.0000000000E+00	1508.239545
9	0.4158888289E-01	0.0000000000E+00	1510.784823
10	0.4150925843E-01	0.0000000000E+00	1513.682861
11	0.4142016032E-01	0.0000000000E+00	1516.938916
12	0.4132155011E-01	0.0000000000E+00	1520.558955
13	0.4121338489E-01	0.0000000000E+00	1524.549688
14	0.4109561752E-01	0.0000000000E+00	1528.918577
15	0.4096819680E-01	0.0000000000E+00	1533.673873
16	0.4083106766E-01	0.0000000000E+00	1538.824642
17	0.4068417123E-01	0.0000000000E+00	1544.380804
18	0.4052744476E-01	0.0000000000E+00	1550.353185
19	0.4036082144E-01	0.0000000000E+00	1556.753575
20	0.4018422979E-01	0.0000000000E+00	1563.594808
21	0.3999759286E-01	0.0000000000E+00	1570.890861
22	0.3980082677E-01	0.0000000000E+00	1578.656982
23	0.3959383877E-01	0.0000000000E+00	1586.909858
24	0.3937652458E-01	0.0000000000E+00	1595.667818
25	0.3914876508E-01	0.0000000000E+00	1604.951087
26	0.3891042253E-01	0.0000000000E+00	1614.782081
27	0.3866133664E-01	0.0000000000E+00	1625.185742
28	0.3840132111E-01	0.0000000000E+00	1636.189883
29	0.3813016132E-01	0.0000000000E+00	1647.825524
30	0.3784761400E-01	0.0000000000E+00	1660.127190
31	0.3755340932E-01	0.0000000000E+00	1673.133125
32	0.3724725578E-01	0.0000000000E+00	1686.885430
33	0.3692884747E-01	0.0000000000E+00	1701.430111
34	0.3659787314E-01	0.0000000000E+00	1716.817063
35	0.3625402627E-01	0.0000000000E+00	1733.100004
36	0.3589701555E-01	0.0000000000E+00	1750.336403
37	0.3552657515E-01	0.0000000000E+00	1768.587397
38	0.3514247440E-01	0.0000000000E+00	1787.917730
39	0.3474452577E-01	0.0000000000E+00	1808.395759
40	0.3433258869E-01	0.0000000000E+00	1830.093665
41	0.3390656461E-01	0.0000000000E+00	1853.088150
42	0.3346637756E-01	0.0000000000E+00	1877.462028
43	0.3301194133E-01	0.0000000000E+00	1903.306820
44	0.3254315545E-01	0.0000000000E+00	1930.724056
45	0.3206016806E-01	0.0000000000E+00	1959.810471
46	0.3156608684E-01	0.0000000000E+00	1990.485973

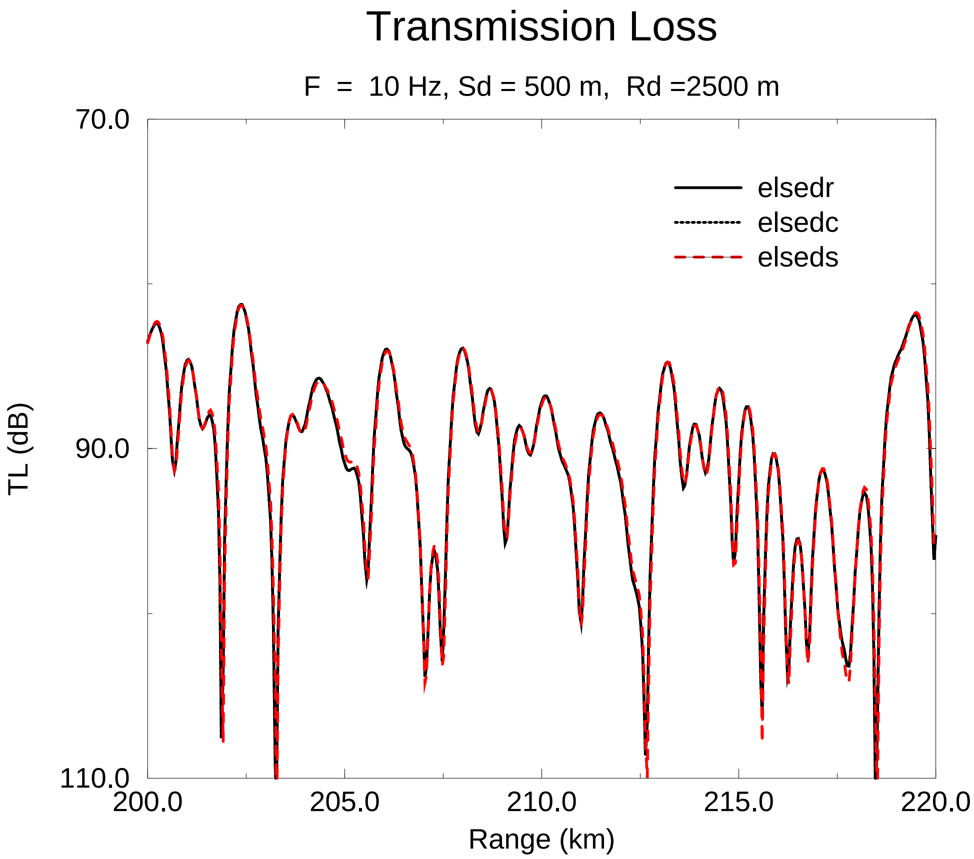

Figure 5.12: Transmission loss for the ELSED problem.

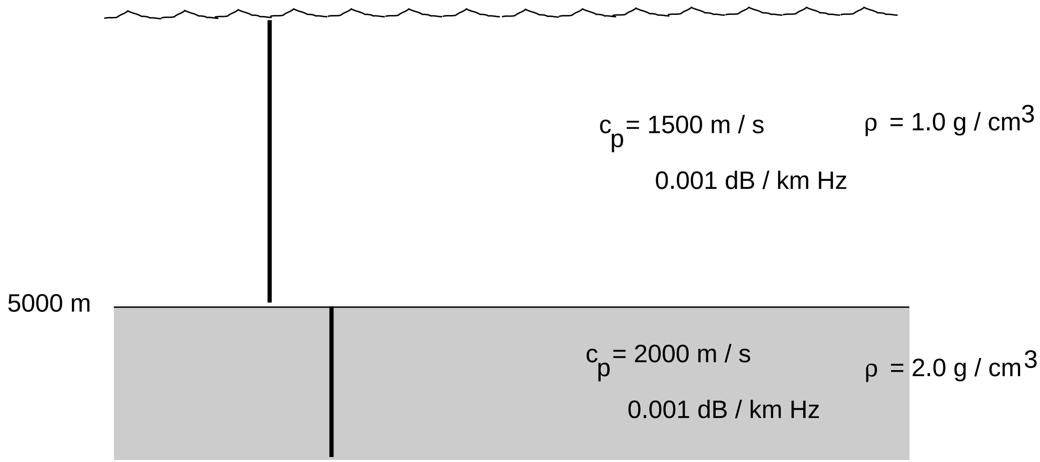

Figure 5.13: Schematic of the ATTEN problem.

5.7 ATTEN

Volume attenuation is included in both ocean and half-space.

```
'Attenuation test .001dB/kmHz'
10.0
1
'NVF'
500 0.0 5000.0
    0.0 1500.0    0.0 1.0 0.001 0.0
 5000.0 1500.0    0.0 1.0 0.001 0.0
'A' 0.0
 5000.0 2000.0    0.0 2.0 0.001 0.0
1400.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Attenuation test .001dB/kmHz
Frequency =   10.00     NMEDIA =   1


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


        ( Number of pts =   500  RMS roughness =  0.000E+00 )
     0.00      1500.00      0.00     1.00       0.0010    0.0000
  5000.00      1500.00      0.00     1.00       0.0010    0.0000

                                 ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      2000.00      0.00     2.00       0.0010    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             5.40
       2             6.08

   I          K                  ALPHA          PHASE SPEED
   1   0.4188332250E-01  -0.1151416386E-05    1500.164011
   2   0.4186958029E-01  -0.1151788191E-05    1500.656387
   3   0.4184666444E-01  -0.1152408844E-05    1501.478168
   4   0.4181455671E-01  -0.1153279807E-05    1502.631094
   5   0.4177323158E-01  -0.1154403131E-05    1504.117606
   6   0.4172265632E-01  -0.1155781449E-05    1505.940863
   7   0.4166279100E-01  -0.1157417981E-05    1508.104752
   8   0.4159358845E-01  -0.1159316538E-05    1510.613905
   9   0.4151499436E-01  -0.1161481525E-05    1513.473723
  10   0.4142694717E-01  -0.1163917959E-05    1516.690400
  11   0.4132937806E-01  -0.1166631476E-05    1520.270955
```

12	0.4122221086E-01	-0.1169628360E-05	1524.223271
13	0.4110536191E-01	-0.1172915566E-05	1528.556134
14	0.4097873990E-01	-0.1176500754E-05	1533.279287
15	0.4084224564E-01	-0.1180392329E-05	1538.403486
16	0.4069577183E-01	-0.1184599493E-05	1543.940568
17	0.4053920269E-01	-0.1189132294E-05	1549.903523
18	0.4037241360E-01	-0.1194001698E-05	1556.306584
19	0.4019527068E-01	-0.1199219655E-05	1563.165318
20	0.4000763032E-01	-0.1204799188E-05	1570.496742
21	0.3980933855E-01	-0.1210754481E-05	1578.319443
22	0.3960023050E-01	-0.1217100991E-05	1586.653721
23	0.3938012964E-01	-0.1223855559E-05	1595.521743
24	0.3914884705E-01	-0.1231036550E-05	1604.947727
25	0.3890618055E-01	-0.1238663998E-05	1614.958142
26	0.3865191376E-01	-0.1246759776E-05	1625.581943
27	0.3838581506E-01	-0.1255347785E-05	1636.850826
28	0.3810763642E-01	-0.1264454167E-05	1648.799531
29	0.3781711218E-01	-0.1274107542E-05	1661.466184
30	0.3751395763E-01	-0.1284339274E-05	1674.892681
31	0.3719786751E-01	-0.1295183771E-05	1689.125138
32	0.3686851435E-01	-0.1306678812E-05	1704.214400
33	0.3652554674E-01	-0.1318865902E-05	1720.216634
34	0.3616858740E-01	-0.1331790655E-05	1737.194002
35	0.3579723127E-01	-0.1345503170E-05	1755.215441
36	0.3541104365E-01	-0.1360058366E-05	1774.357562
37	0.3500955864E-01	-0.1375516165E-05	1794.705661
38	0.3459227827E-01	-0.1391941313E-05	1816.354869
39	0.3415867357E-01	-0.1409402284E-05	1839.411385
40	0.3370818980E-01	-0.1427967936E-05	1863.993689
41	0.3324026214E-01	-0.1447697921E-05	1890.233381
42	0.3275436104E-01	-0.1468612832E-05	1918.274424
43	0.3225014365E-01	-0.1490575913E-05	1948.265835
44	0.3172824616E-01	-0.1512451223E-05	1980.312834

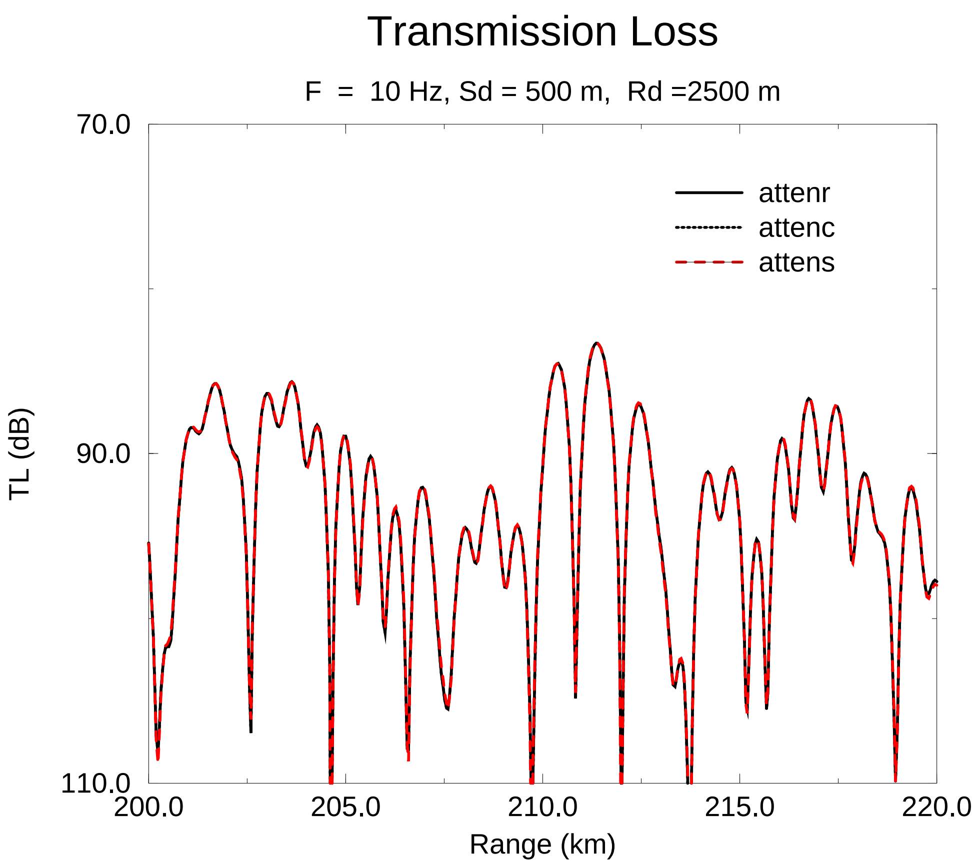

Figure 5.14: Transmission loss for the ATTEN problem.

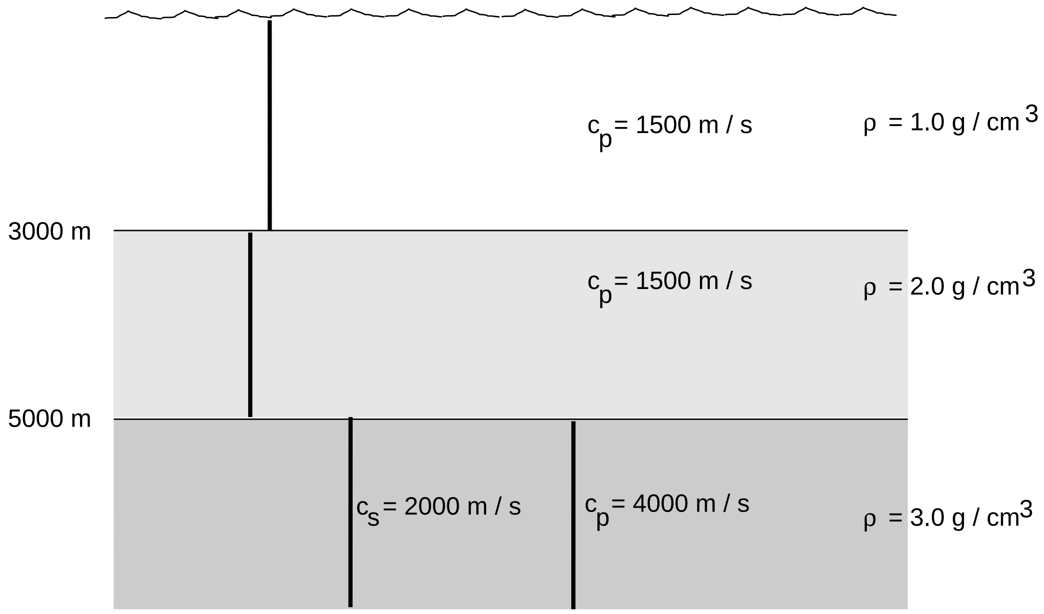

Figure 5.15: Schematic of the NORMAL problem.

5.8 NORMAL

Mode normalization is checked using several density changes. Due to the shear in the lower halfspace, there is a Scholte wave with a phase velocity of about 1393 m/s. It has been excluded from the calculation.

```
'Mode normalization test'
10.0
2
'NVF'
300 0.0 3000.0
    0.0 1500.0 /
 3000.0 1500.0 /
200 0.0 5000.0
 3000.0 1500.0    0.0 2.0 /
 5000.0 1500.0    0.0 2.0 /
'A' 0.0
 5000.0 4000.0 2000.0 3.0 /
1400.0 2000.0
1000.0                    ! RMAX (km)
1  500.0 /                ! NSD  SD(1:NSD)
1 2500.0 /                ! NRD  RD(1:NRD)
```

```
KRAKEN- Mode normalization test
Frequency =   10.00     NMEDIA =   2


    N2-LINEAR approximation to SSP
    Attenuation units: dB/mkHz
    VACUUM


     Z           ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =   300  RMS roughness =  0.000E+00 )
     0.00       1500.00      0.00      1.00       0.0000    0.0000
  3000.00       1500.00      0.00      1.00       0.0000    0.0000

         ( Number of pts =   200  RMS roughness =  0.000E+00 )
  3000.00       1500.00      0.00      2.00       0.0000    0.0000
  5000.00       1500.00      0.00      2.00       0.0000    0.0000

                                ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00       4000.00   2000.00      3.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             5.55
       2             6.40
       4             4.54

   I            K                ALPHA          PHASE SPEED
   1    0.4188367900E-01   0.0000000000E+00    1500.151242
   2    0.4186658699E-01   0.0000000000E+00    1500.763678
   3    0.4184753177E-01   0.0000000000E+00    1501.447049
   4    0.4180919493E-01   0.0000000000E+00    1502.823797
   5    0.4176674150E-01   0.0000000000E+00    1504.351329
   6    0.4171909765E-01   0.0000000000E+00    1506.069321
```

7	0.4164470397E-01	0.0000000000E+00	1508.759748
8	0.4158680917E-01	0.0000000000E+00	1510.860158
9	0.4149472381E-01	0.0000000000E+00	1514.213069
10	0.4140185763E-01	0.0000000000E+00	1517.609515
11	0.4131280307E-01	0.0000000000E+00	1520.880899
12	0.4117924681E-01	0.0000000000E+00	1525.813557
13	0.4108058576E-01	0.0000000000E+00	1529.478022
14	0.4093552018E-01	0.0000000000E+00	1534.898123
15	0.4078858493E-01	0.0000000000E+00	1540.427381
16	0.4065836697E-01	0.0000000000E+00	1545.360961
17	0.4046343001E-01	0.0000000000E+00	1552.805905
18	0.4032142497E-01	0.0000000000E+00	1558.274617
19	0.4012239980E-01	0.0000000000E+00	1566.004361
20	0.3991798210E-01	0.0000000000E+00	1574.023780
21	0.3974491332E-01	0.0000000000E+00	1580.877849
22	0.3948540371E-01	0.0000000000E+00	1591.267840
23	0.3929733220E-01	0.0000000000E+00	1598.883424
24	0.3904083516E-01	0.0000000000E+00	1609.388037
25	0.3877585468E-01	0.0000000000E+00	1620.386026
26	0.3855610943E-01	0.0000000000E+00	1629.621194
27	0.3822733064E-01	0.0000000000E+00	1643.636948
28	0.3799085539E-01	0.0000000000E+00	1653.867817
29	0.3766977091E-01	0.0000000000E+00	1667.964831
30	0.3734233184E-01	0.0000000000E+00	1682.590507
31	0.3706900744E-01	0.0000000000E+00	1694.996910
32	0.3666482678E-01	0.0000000000E+00	1713.681983
33	0.3637907870E-01	0.0000000000E+00	1727.142504
34	0.3598056675E-01	0.0000000000E+00	1746.271911
35	0.3559408137E-01	0.0000000000E+00	1765.233169
36	0.3525354551E-01	0.0000000000E+00	1782.284652
37	0.3477030998E-01	0.0000000000E+00	1807.054729
38	0.3443753112E-01	0.0000000000E+00	1824.516771
39	0.3393983898E-01	0.0000000000E+00	1851.271395
40	0.3351944923E-01	0.0000000000E+00	1874.489424
41	0.3307617837E-01	0.0000000000E+00	1899.610419
42	0.3254372213E-01	0.0000000000E+00	1930.690436
43	0.3214824698E-01	0.0000000000E+00	1954.441034
44	0.3155272679E-01	0.0000000000E+00	1991.328784

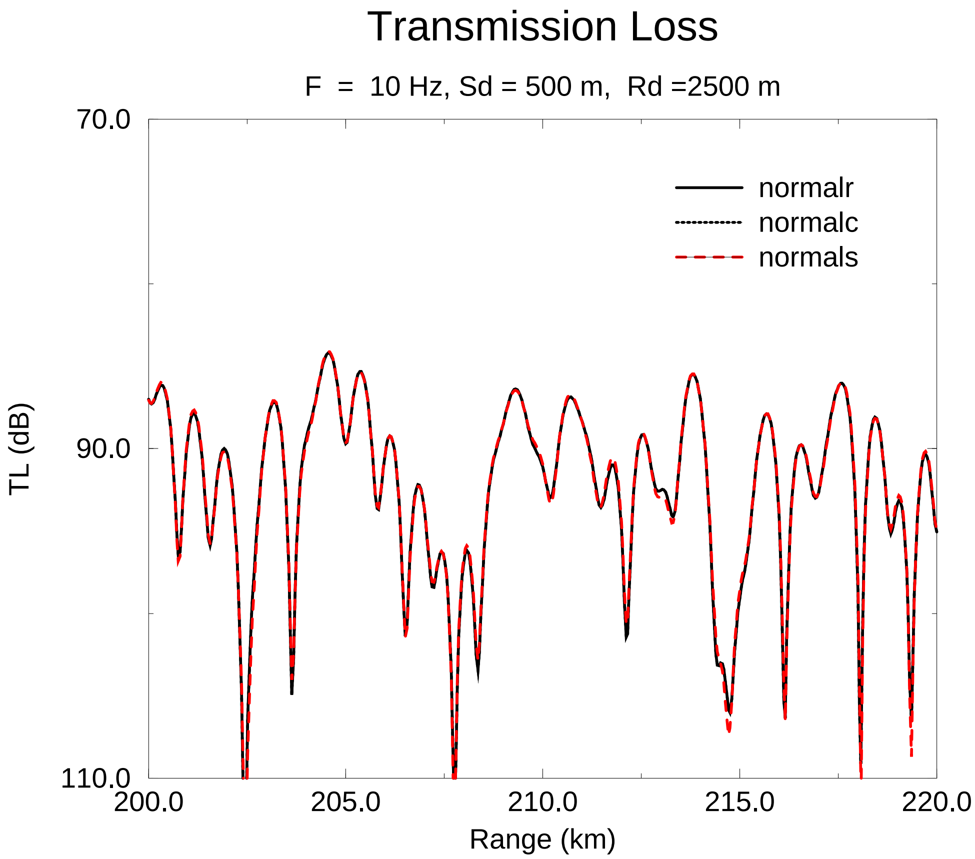

Figure 5.16: Transmission loss for the NORMAL problem.

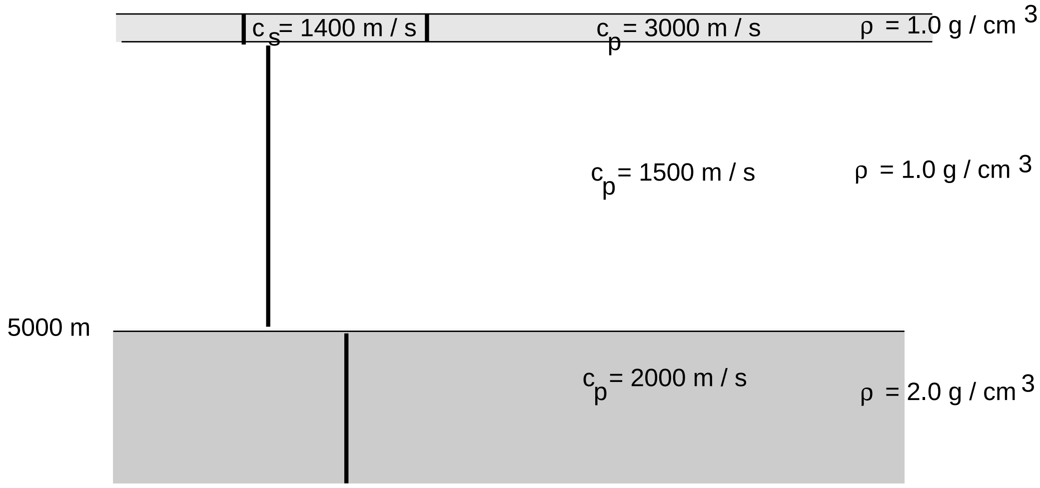

Figure 5.17: Schematic of the ICE problem.

5.9 ICE

This problem is loosely based on an Arctic scenario with an elastic ice-canopy. Here the elastic medium lies above the acoustic media. Note that the KRAKEN result disagrees with both KRAKENC and SCOOTER. This is expected since KRAKEN ignores attenuation in elastic media.

```
'Ice problem'
10.0
2
'NVW'
50 0.0 30.0
     0.0 3000.0 1400.0 1.0 0.3 1.0
    30.0 3000.0 1400.0 1.0 0.3 1.0
500 0.0 5000.0
    30.0 1500.0    0.0 1.0 0.0 0.0
  5000.0 1500.0    0.0 1.0 0.0 0.0
'A' 0.0
  5000.0 2000.0    0.0 2.0 0.0 0.0
1400.0 2000.0
1000.0                  ! RMAX (km)
1  500.0 /              ! NSD  SD(1:NSD)
1 2500.0 /              ! NRD  RD(1:NRD)
```

```
KRAKEN- Ice problem
Frequency =   10.00     NMEDIA =   2


    N2-LINEAR approximation to SSP
    Attenuation units: dB/wavelength
    VACUUM


     Z          ALPHAR     BETAR      RHO       ALPHAI     BETAI


         ( Number of pts =    50  RMS roughness =  0.000E+00 )
     0.00      3000.00   1400.00     1.00       0.3000    1.0000
    30.00      3000.00   1400.00     1.00       0.3000    1.0000

         ( Number of pts =   500  RMS roughness =  0.000E+00 )
    30.00      1500.00      0.00     1.00       0.0000    0.0000
  5000.00      1500.00      0.00     1.00       0.0000    0.0000

                                ( RMS roughness =  0.000E+00 )
    ACOUSTO-ELASTIC half-space
  5000.00      2000.00      0.00     2.00       0.0000    0.0000

CLOW =   1400.0      CHIGH =   2000.0
RMAX =    1000.000000000000

Number of sources   =            1
  500.0000

Number of receivers =            1
  2500.000

Mesh multiplier   CPU seconds
       1             11.5
       2             16.6

   I           K                  ALPHA          PHASE SPEED
   1   0.4188333139E-01   0.0000000000E+00    1500.163692
   2   0.4186961576E-01   0.0000000000E+00    1500.655115
   3   0.4184674417E-01   0.0000000000E+00    1501.475307
   4   0.4181469833E-01   0.0000000000E+00    1502.626004
   5   0.4177345263E-01   0.0000000000E+00    1504.109646
   6   0.4172297425E-01   0.0000000000E+00    1505.929388
   7   0.4166322309E-01   0.0000000000E+00    1508.089111
```

8	0.4159415182E-01	0.0000000000E+00	1510.593445
9	0.4151570588E-01	0.0000000000E+00	1513.447784
10	0.4142782343E-01	0.0000000000E+00	1516.658320
11	0.4133043533E-01	0.0000000000E+00	1520.232066
12	0.4122346498E-01	0.0000000000E+00	1524.176900
13	0.4110682824E-01	0.0000000000E+00	1528.501608
14	0.4098043325E-01	0.0000000000E+00	1533.215930
15	0.4084418017E-01	0.0000000000E+00	1538.330622
16	0.4069796094E-01	0.0000000000E+00	1543.857521
17	0.4054165894E-01	0.0000000000E+00	1549.809621
18	0.4037514862E-01	0.0000000000E+00	1556.201159
19	0.4019829503E-01	0.0000000000E+00	1563.047712
20	0.4001095339E-01	0.0000000000E+00	1570.366306
21	0.3981296844E-01	0.0000000000E+00	1578.175543
22	0.3960417391E-01	0.0000000000E+00	1586.495737
23	0.3938439178E-01	0.0000000000E+00	1595.349077
24	0.3915343149E-01	0.0000000000E+00	1604.759805
25	0.3891108916E-01	0.0000000000E+00	1614.754417
26	0.3865714660E-01	0.0000000000E+00	1625.361895
27	0.3839137032E-01	0.0000000000E+00	1636.613972
28	0.3811351037E-01	0.0000000000E+00	1648.545423
29	0.3782329915E-01	0.0000000000E+00	1661.194409
30	0.3752045003E-01	0.0000000000E+00	1674.602864
31	0.3720465592E-01	0.0000000000E+00	1688.816938
32	0.3687558766E-01	0.0000000000E+00	1703.887506
33	0.3653289237E-01	0.0000000000E+00	1719.870752
34	0.3617619171E-01	0.0000000000E+00	1736.828840
35	0.3580508009E-01	0.0000000000E+00	1754.830681
36	0.3541912307E-01	0.0000000000E+00	1773.952815
37	0.3501785613E-01	0.0000000000E+00	1794.280405
38	0.3460078429E-01	0.0000000000E+00	1815.908349
39	0.3416738384E-01	0.0000000000E+00	1838.942465
40	0.3371710848E-01	0.0000000000E+00	1863.500635
41	0.3324940638E-01	0.0000000000E+00	1889.713529
42	0.3276376704E-01	0.0000000000E+00	1917.723716
43	0.3225987273E-01	0.0000000000E+00	1947.678269
44	0.3173836536E-01	0.0000000000E+00	1979.681448

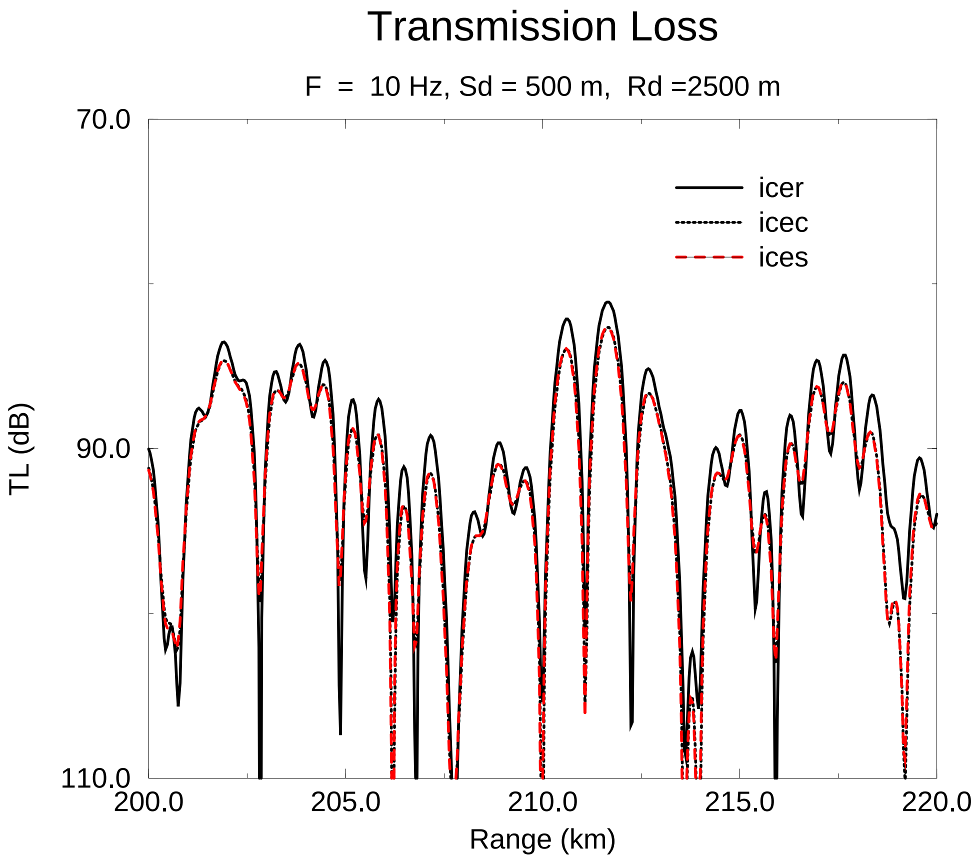

Figure 5.18: Transmission loss for the ICE problem.

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