UNIVERSITÀ
DEGLI STUDI DI TRIESTE

dipartimento di matematica e geoscienze

The DMG Manuals

WKBJ Modal Summation Technique

Computation of synthetic seismograms for P-SV and SH waves

Document name: DMGwkbj.pdf
Document Version: 1.0
Date Issued: September 26, 2017 3:51 PM

Author: Fabio Romanelli, Franco Vaccari

University of Trieste
Department of Mathematic and Geosciences
Group of Seismology
via Weiss, 4
34128 Trieste, Italy

Table of Contents

Foreword

Logging in and getting to the working directory

Six accounts have been made available for the students:

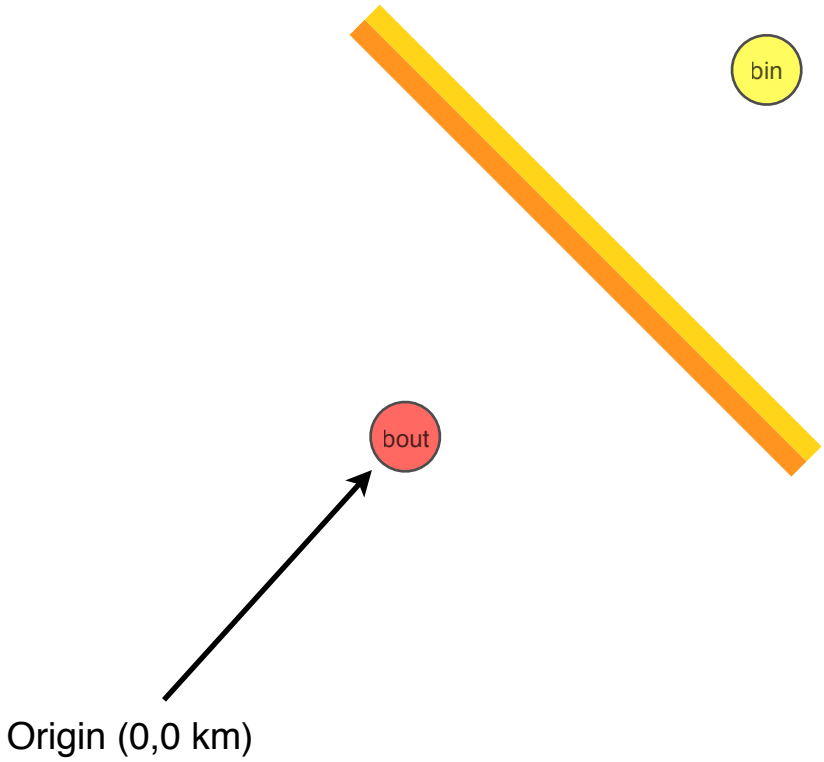
Username:	sg01	sg02	sg03	sg04	sg05	sg06
Password:	...	...	...	...	...	...

From the computer used to login into the system, connect to is01 server, using the Terminal application:

```
[it01:/XDST/sg01] sg01% ssh is01
[is01:/XDST/sg01] sg01%
```

2D Model description

The geometry of the 2D model used for this exercise is illustrated in the figure below, where the transition zone between the two initial structures is shown by the shaded area..



P-SV waves

Example input files for P-SV waves

Required input files can be found in **/XDST/Examples/WKBJ/2D/Ray/Base** directory:

```
[is01:/tmpXDST/sg01] sg01% ls -l /XDST/Examples/WKBJ/2D/Ray/Base/
total 32
-rw-r--r-- 1 vaccari dstguest 2803 Apr 10 17:25 bin.stp
-rw-r--r-- 1 vaccari dstguest 2803 Apr 10 17:25 bout.stp
-rw-r--r-- 1 vaccari dstguest  949 Apr 10 17:25 intergenstru.par
-rwxr-xr-x 1 vaccari dstguest 2409 Apr 10 17:25 rwkbj.box
-rwxr-xr-x 1 vaccari dstguest  721 Apr 10 17:25 rwkbj.cnt
-rw-r--r-- 1 vaccari dstguest   89 Apr 10 17:25 syn2ftan.par
-rw-r--r-- 1 vaccari dstguest   88 Apr 10 17:25 syn2xy.par
-rwxr-xr-x 1 vaccari dstguest 1065 Apr 10 17:25 tau.par
[is01:/tmpXDST/sg01] sg01%
```

To get to the working directory and copy the required input files, give the following commands:

```
[is01:/tmpXDST/sg01] sg01% cdt
[is01:/tmpXDST/sg01] sg01% mkdir -p WKBJ/2D
[is01:/tmpXDST/sg01] sg01% cd WKBJ/2D/
[is01:sg01/WKBJ/2D] sg01% cp /XDST/Examples/WKBJ/2D/Ray/Base/* .
[is01:sg01/WKBJ/2D] sg01%
```

Programs execution

1) Create the interpolated structures:

   intergenstru.out

2) Prepare the structures and generate the modes:

   inter.job

3) Convert the modes files from sequential (`.spr`) to direct access files (`.sdr` + `.sir`) for the desired source and receiver `.spr` files

   modes2daf01.out

```
  NUMBER OF SPECTRA (MAX 29)
2
           2
  SPECTRUM TYPE (1=LOVE 2=RAYLEIGH):
2
           2

 SEQUENTAL INPUT SPECTRUM           1  (MAX 20 CHARACTERS)
bin.spr

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bin.spr
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bin.sdr
 SPECTRAL INFORMATION FILE...................: bin.sir

 SEQUENTAL INPUT SPECTRUM           2  (MAX 20 CHARACTERS)
bout.spr

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bout.spr
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bout.sdr
 SPECTRAL INFORMATION FILE...................: bout.sir
```

4) Perform the arrival time (tau) and geometrical spreading (J) computation. The output file with extension `.wkbjr`, containing tau and J for the path, has to be used for the computation of the synthetic seismograms, and must be referenced in file `rwkbj.cnt`.

`tauj2D.out`

5) Generate the synthetic seismograms. Check the `rwkbj.cnt` file where the `rwkbj.box` file contains the specification of the source parameters.

`rwkbj2D.out`

6) To plot the seismograms, a simple time-amplitude file can be generated using program *`syn2xy.out`* that requires file `syn2xy.par` with the list of files to be converted. Once the files with extension .xy are produced by , they can be plotted with any general-purpose plotting software, like for instance *`gnuplot`*.

```
gnuplot> plot "filename" w l
gnuplot> plot "filename1" w l, "filename2"
```

SH waves

Example input files

Required input files can be found in **/XDST/Examples/WKBJ/2D/Lov/Base** directory:

```
[is01:/tmpXDST/sg01] sg01% ls -l /XDST/Examples/WKBJ/2D/Lov/Base
total 32
-rw-r--r-- 1 vaccari dstguest 2803 Jan 16 19:21 bin.stp
-rw-r--r-- 1 vaccari dstguest 2803 Jan 16 19:21 bout.stp
-rw-r--r-- 1 vaccari dstguest  929 Mar 31 10:58 intergenstru.par
-rwxr-xr-x 1 vaccari dstguest 2320 Apr  8  2013 lwkbj.box
-rwxr-xr-x 1 vaccari dstguest  721 Apr 10 17:39 lwkbj.cnt
-rw-r--r-- 1 vaccari dstguest   89 Apr 10 17:38 syn2ftan.par
-rw-r--r-- 1 vaccari dstguest   88 Apr 10 17:38 syn2xy.par
-rwxr-xr-x 1 vaccari dstguest 1065 Apr 10 17:37 tau.par
[is01:/tmpXDST/sg01] sg01%
```

To get to the working directory and copy the required input files, give the following commands:

```
[is01:/tmpXDST/sg01] sg01% cdt
[is01:/tmpXDST/sg01] sg01% mkdir -p WKBJ/2D/Lov
[is01:/tmpXDST/sg01] sg01% cd WKBJ/2D/Lov/
[is01:WKBJ/2D/Lov] sg01% cp /XDST/Examples/WKBJ/2D/Lov/Base/* .
[is01:WKBJ/2D/Lov] sg01%
```

Programs execution

1) Create the interpolated structures:

   intergenstru.out

2) Prepare the structures and generate the modes:

   inter.job

3) Convert the modes files from sequential (`.spr`) to direct access files (`.sdr` + `.sir`) for the desired source and receiver `.spr` files

   modes2daf01.out

```
  NUMBER OF SPECTRA (MAX 29)
2
           2
  SPECTRUM TYPE (1=LOVE 2=RAYLEIGH):
1
           1

 SEQUENTAL INPUT SPECTRUM           1  (MAX 20 CHARACTERS)
bin.spl

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bin.spl
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bin.sdl
 SPECTRAL INFORMATION FILE...................: bin.sil

 SEQUENTAL INPUT SPECTRUM           2  (MAX 20 CHARACTERS)
bout.spl

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bout.spl
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bout.sdl
 SPECTRAL INFORMATION FILE...................: bout.sil
```

4) Perform the arrival time (tau) and geometrical spreading (J) computation. The output file with extension `.wkbjl`, containing tau and J for the path, has to be used for the computation of the synthetic seismograms, and must be referenced in file `lwkbj.cnt`.

`tauj2D.out`

5) Generate the synthetic seismograms. Check the `lwkbj.cnt` file where the `lwkbj.box` file contains the specification of the source parameters.

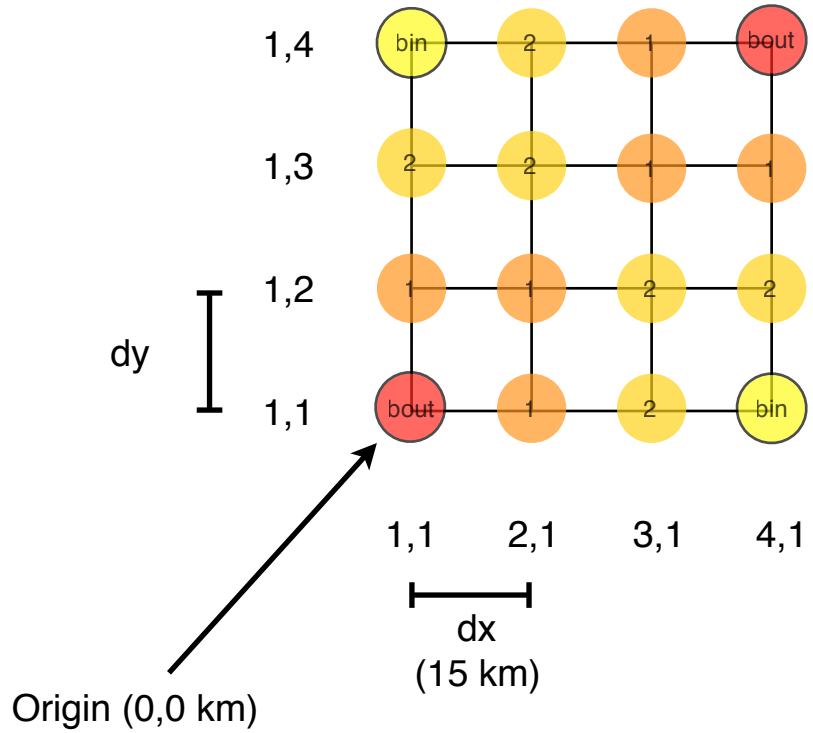
`lwkbj2D.out`

6) To plot the seismograms, a simple time-amplitude file can be generated using program *`syn2xy.out`* that requires file `syn2xy.par` with the list of files to be converted. Once the files with extension .xy are produced by , they can be plotted with any general-purpose plotting software, like for instance *`gnuplot`*.

```
gnuplot> plot "filename" w l
gnuplot> plot "filename1" w l, "filename2"
```

3D Model description

The geometry of the 3D model used for this exercise is illustrated in the figure below, where each knot of the grid is associated with a 1D layered structural model.



File `inp3D.par`, listed below, describes the model. For P-SV computations, the Rayleigh modes files (`.spr`) are associated with the grid knots, while for SH computations the corresponding `.spl` files must be used.

```
1.0 Frequency (Hz)
4 4 (Columns, Rows)
0. 0. 15. 15. (km) origin coords (x y) and step (dx, dy)
1 1 bout.spr
1 2 bacb001.spr
1 3 bacb002.spr
1 4 bin.spr
2 1 bacb001.spr
2 2 bacb001.spr
2 3 bacb002.spr
2 4 bacb002.spr
3 1 bacb002.spr
3 2 bacb002.spr
3 3 bacb001.spr
3 4 bacb001.spr
4 1 bin.spr
4 2 bacb002.spr
4 3 bacb001.spr
4 4 bout.spr
```

P-SV waves

Example input files for P-SV waves

Required input files can be found in **/XDST/Examples/WKBJ/3D/Ray/Base** directory:

```
[is01:WKBJ/3D/Ray] sg01% ls -l /XDST/Examples/WKBJ/3D/Ray/Base/
total 32
-rw-r--r-- 1 vaccari dstguest 2803 Apr  1 00:09 bin.stp
-rw-r--r-- 1 vaccari dstguest 2803 Apr  1 00:09 bout.stp
-rw-r--r-- 1 vaccari dstguest  338 Apr  1 00:09 inp3D.par
-rw-r--r-- 1 vaccari dstguest  967 Apr  1 00:09 intergenstru.par
-rw-r--r-- 1 vaccari dstguest 2411 Apr  1 00:09 rwkbj.box
-rw-r--r-- 1 vaccari dstguest  739 Apr  1 00:09 rwkbj.cnt
-rw-r--r-- 1 vaccari dstguest   87 Apr  1 00:09 syn2xy.par
-rw-r--r-- 1 vaccari dstguest  593 Apr  1 00:09 tau3D.par
[is01:WKBJ/3D/Ray] sg01%
```

To get to the working directory and copy the required input files, give the following commands:

```
[is01:/XDST/sg01] sg01% cdt
[is01:/tmpXDST/sg01] sg01% cd WKBJ/3D/Ray
[is01:WKBJ/3D/Ray] sg01% cp /XDST/Examples/WKBJ/3D/Ray/Base/* .
```

Programs execution

7) Create the interpolated structures:

   intergenstru.out

8) Prepare the structures and generate the modes:

   inter.job

9) Prepares, from the set of spectra files corresponding to the structures uniformly distributed on a grid (as defined in file `inp3D.par`), a file (`tau3D.inp`) containing, for each mode-frequency combination, the information on phase velocity, phase attenuation, and an "interpolated velocity" in each grid point

   inp3D.out

10) Determines the structures at the source and immediately before the receiver position. The coordinates of source and receiver are set in file `tau3D.par`. Files `tau_src.pri` and `tau_rec.pri` will contain the names of the `.spr` files associated with source and receiver.

   detstru.out

11) Convert the modes files from sequential (`.spr`) to direct access files (`.sdr` + `.sir`) for the source and receiver `.spr` files identified in the previous step

   modes2daf01.out

```
  NUMBER OF SPECTRA (MAX 29)
2
           2
  SPECTRUM TYPE (1=LOVE 2=RAYLEIGH):
2
           2

 SEQUENTAL INPUT SPECTRUM           1  (MAX 20 CHARACTERS)
bout.spr

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bout.spr
```

```
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bout.sdr
 SPECTRAL INFORMATION FILE..................: bout.sir

 SEQUENTAL INPUT SPECTRUM           2  (MAX 20 CHARACTERS)
bacb001.spr

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bacb001.spr
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bacb001.sdr
 SPECTRAL INFORMATION FILE..................: bacb001.sir
```

12) Perform the two-point dynamic ray tracing at a plane surface given the coordinates of source and receiver, velocity and attenuation in the grid points, initial grid points x0,y0, steps in x and y, number of points along x and y. The output file with extension `.3wkbjr`, containing the arrival time and geometrical spreading for the path, has to be used for the computation of synthetic seismograms, and must be referenced in file `rwkbj.cnt`.

    raytrace3D.out

13) Generate the synthetic seismograms. Check the `rwkbj.cnt` file where the `rwkbj.box` file contains the specification of the source parameters.

    rwkbj3D.out

14) To plot the seismograms, a simple time-amplitude file can be generated using program *syn2xy.out* that requires file `syn2xy.par` with the list of files to be converted. Once the files with extension .xy are produced by , they can be plotted with any general-purpose plotting software, like for instance *gnuplot*.

```
gnuplot> plot "filename" w l
gnuplot> plot "filename1" w l, "filename2"
```

SH waves

Example input files

Required input files can be found in **/XDST/Examples/WKBJ/3D/Lov/Base** directory:

```
[is01:WKBJ/3D/Lov] sg01% ls -l /XDST/Examples/WKBJ/3D/Lov/Base/
total 32
-rw-r--r-- 1 vaccari dstguest 2803 Apr  1 00:09 bin.stp
-rw-r--r-- 1 vaccari dstguest 2803 Apr  1 00:09 bout.stp
-rw-r--r-- 1 vaccari dstguest  338 Apr  1 00:09 inp3D.par
-rw-r--r-- 1 vaccari dstguest  967 Apr  1 00:09 intergenstru.par
-rw-r--r-- 1 vaccari dstguest 2320 Apr  1 00:09 lwkbj.box
-rw-r--r-- 1 vaccari dstguest  739 Apr  1 00:09 lwkbj.cnt
-rw-r--r-- 1 vaccari dstguest   87 Apr  1 00:09 syn2xy.par
-rw-r--r-- 1 vaccari dstguest  593 Apr  1 00:09 tau3D.par
[is01:WKBJ/3D/Lov] sg01%
```

To get to the working directory and copy the required input files, give the following commands:

```
[is01:/XDST/sg01] sg01% cdt
[is01:/tmpXDST/sg01] sg01% cd WKBJ/3D/Lov
[is01:WKBJ/3D/Lov] sg01% cp /XDST/Examples/WKBJ/3D/Lov/Base/* .
```

Programs execution

1) Create the interpolated structures:

   intergenstru.out

2) Prepare the structures and generate the modes:

   inter.job

3) Prepares, from the set of spectra files corresponding to the structures uniformly distributed on a grid (as defined in file `inp3D.par`), a file (`tau3D.inp`) containing, for each mode-frequency combination, the information on phase velocity, phase attenuation, and an "interpolated velocity" in each grid point

   inp3D.out

4) Determines the structures at the source and immediately before the receiver position. The coordinates of source and receiver are set in file `tau3D.par`. Files `tau_src.pri` and `tau_rec.pri` contain the names of the `.spl` files associated with source and receiver.

   detstru.out

5) Convert the modes files from sequential (`.spl`) to direct access files (`.sdl` + `.sil`) for the source and receiver `.spr` files identified in the previous step

   modes2daf01.out

```
  NUMBER OF SPECTRA (MAX 29)
2
           2
  SPECTRUM TYPE (1=LOVE 2=RAYLEIGH):
1
           1

 SEQUENTAL INPUT SPECTRUM           1  (MAX 20 CHARACTERS)
bout.spl

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bout.spl
```

```
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bout.sdl
 SPECTRAL INFORMATION FILE..................: bout.sil

 SEQUENTAL INPUT SPECTRUM           2  (MAX 20 CHARACTERS)
bacb001.spl

 INPUT  SPECTRUM (FORMATTED SEQUENTIAL)......: bacb001.spl
 OUTPUT SPECTRUM (FORMATTED DIRECT ACCESS)...: bacb001.sdl
 SPECTRAL INFORMATION FILE..................: bacb001.sil
```

6) Perform the two-point dynamic ray tracing at a plane surface given the coordinates of source and receiver, velocity and attenuation in the grid points, initial grid points x0,y0, steps in x and y, number of points along x and y. The output file with extension `.3wkbjl`, containing the arrival time and geometrical spreading for the path, has to be used for the computation of synthetic seismograms, and must be referenced in file `lwkbj.cnt`.

   raytrace3D.out

7) Generate the synthetic seismograms. Check the `lwkbj.cnt` file where the `lwkbj.box` file contains the specification of the source parameters.

   lwkbj3D.out

8) To plot the seismograms, a simple time-amplitude file can be generated using program *syn2xy.out* that requires file `syn2xy.par` with the list of files to be converted. Once the files with extension .xy are produced by , they can be plotted with any general-purpose plotting software, like for instance *gnuplot*.

   gnuplot> plot "filename" w l
   gnuplot> plot "filename1" w l, "filename2"

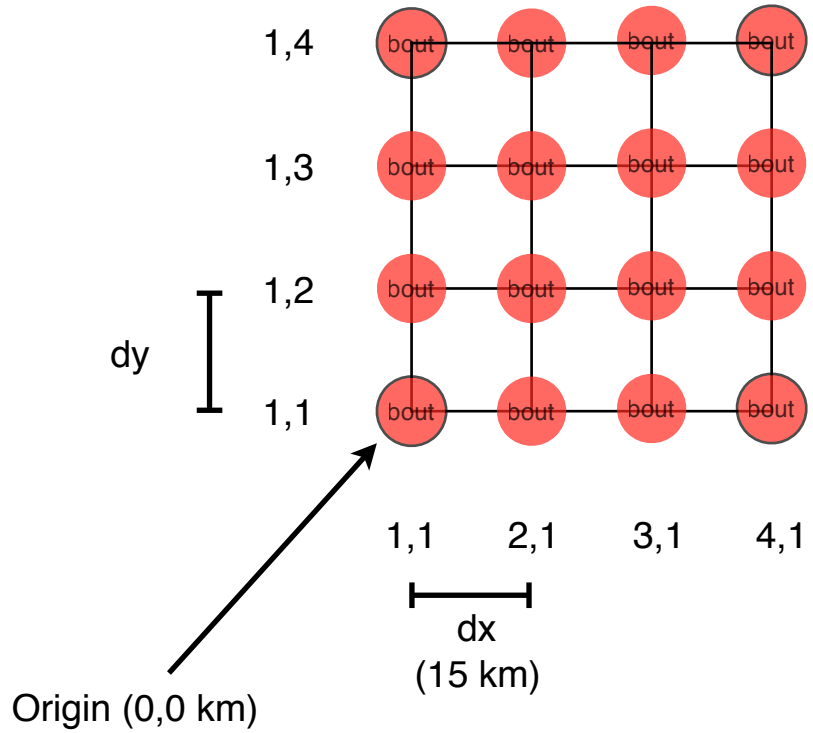
Variations

In the following, some variations are proposed that require some manual editing of input files.

1D model (WKBJ)

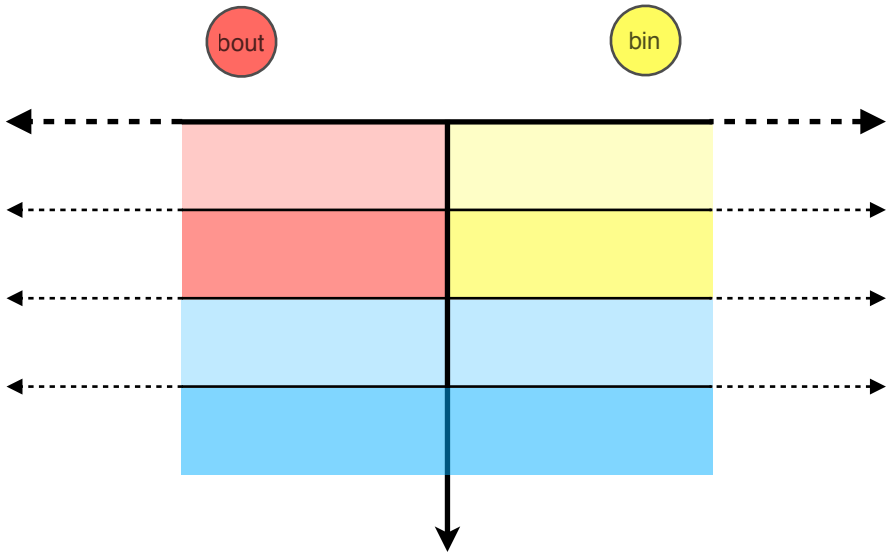
For the P-SV case, using the same programs that handle the 3D case, modify the grid to consider a 1D layered model for the region, and compare the signals obtained with the standard modal summation technique.

Required input files can be found in **/XDST/Examples/WKBJ/3D/RayTest1D/Base** directory.



2D model (Couplings)

Here, synthetic seismograms are generated with the mode coupling technique. The required input files for the P-SV case are available in **/XDST/Examples/WKBJ/3D/RayTest2DCoup/Base** directory.



Appendix 1 - Brief description of WKBJ 3D programs I/O

intergenstru.out

Input files

intergenstru.par

This is the parameter file where the user configures the structure preparation.

```
bacb                      generic name for interpolated structures (max 12 chars)
bout.stp                  first structure
bin.stp                   second structure
0                         reference structure (.str, 0=no reference)
1.d+00    maximum frequency
0         method (0 - stratification equalization, 1 - layers'thickness variation)
0         smooth criteria for WKBJ:(0-weak,1-strong)
0         length (Km) of transition zone (0 - no prefixed)
-1        Schwab's interpolation criterium: (-1)-weak, 0-normal, 1-strong
1         wave (0 - both, 1 - Rayleigh, 2 -Love, other - only str calculation)
Note: Program prepares and runs a scrip for calculating real structures (.str)
      and spectra. Spectra calculation is controlled by last parameter ("ionda"
      in the program). If you don't want to calculate spectra put other value
      than (0,1,2). Nevertheless, the corresponding ray.par and lov.par inputs
      files are prepared always
```

**.stp*

Two files has to be prepared describing the properties of the layered structural models at the source and at the receivers. An example is given below.

```
   thk(km)       rho    vp(km/s)  vs(km/s)    qp       qs
     0.200     2.233     2.800     1.400   300.000   150.000
     0.300     2.267     3.200     1.533   300.000   150.000
     0.500     2.300     3.600     1.700   400.000   200.000
     1.000     2.400     4.200     2.300   400.000   200.000
     2.000     2.830     5.800     3.300   400.000   200.000
     2.000     2.850     6.200     3.500   400.010   200.000
     8.000     2.850     6.200     3.500   400.000   200.000
     2.000     2.860     6.200     3.550   400.010   200.000
    21.000     2.870     6.500     3.700   400.000   200.000
     3.000     2.900     7.000     4.000   400.000   200.000
     3.000     3.100     7.500     4.300   400.000   200.000
    40.000     3.350     8.100     4.500   400.000   200.000
    17.000     3.350     8.150     4.510   750.000   300.000
   100.000     3.410     8.250     4.520   750.000   300.000
   100.000     3.530     8.380     4.540   750.000   300.000
    50.000     3.580     8.620     4.680   750.000   300.000
    50.000     3.620     8.870     4.850   750.000   300.000
    50.000     3.690     9.150     5.040   750.000   300.000

...
...

    25.000     4.450    11.224     6.250  1045.000   475.000
    25.000     4.470    11.267     6.275  1100.000   500.010
    25.000     4.500    11.310     6.297  1165.990   529.990
    25.000     4.530    11.350     6.322  1232.010   560.000
    25.000     4.550    11.392     6.340  1320.010   600.000
    25.000     4.580    11.434     6.360  1375.000   624.980
    25.000     4.600    11.476     6.375  1452.020   659.970
    25.000     4.630    11.518     6.390  1506.990   685.000
    25.000     4.660    11.560     6.405  1584.000   720.010
    25.000     4.680    11.600     6.421  1650.020   749.970
```

.str

In case the depth reached by the structures defined in `.stp` files is not enough, a reference structure must be defined. It can be obtained from a .stp file by using program p5r.out as described in the manual describing the 1D modal summation technique.

Output files

After program *`intergenstru.out`* is executed, the following output files are generated:

bacb.pri

Output writings summarizing the execution

bacb001.stp, bacb002.stp

The new structural model interpolated between the two structures provided by the user

bacb_l_.tau

The tau values for the Love case, for each structure

```
bout.spl
 0.4734280441264029D-01
bacb001.spl
 0.9468560882528058D-01
bacb002.spl
 0.9468560882528058D-01
bin.spl
 0.4734280441264029D-01
```

bacb_r_.tau

The tau values for the Rayleigh case, for each structure

```
bout.spr
 0.4734280441264029D-01
bacb001.spr
 0.9468560882528058D-01
bacb002.spr
 0.9468560882528058D-01
bin.spr
 0.4734280441264029D-01
```

checksp.inp

The input file for program *`checksp.out that`* will check if the the completeness of modes for the structures (generated by programs *`lov`* and *`ray`*, called by the *`inter.job`* shell script). The file will be actually overwritten by the execution of *`inter.job`* (see below) so that the proper `.spl` (or `.spr`) files will be listed.

```
bacb001.spl
bacb002.spl
```

ingen3.chk

```
 total depth   1120.0000000000000
 metodo e layers           0          45
 each rho            1  1.32000000000000572E-002   2.1669999999999998
2.1669999999999998        2427.0400000000000       1.32000000000000572E-002
5.43872371283541140E-006
 each vp             1   1.0658999999999998        3.4238599999999990
0.0000000000000000        3834.7231999999990         1.0658999999999998
2.77960088488264298E-004
 each vs             1  0.35092199999999985        2.6220700000000003
0.0000000000000000        2936.7184000000002        0.35092199999999985
1.19494603227874978E-004
 each rho            2  1.01999999999999418E-002   2.2330000000000001
2.2330000000000001        2500.9600000000000       2.33999999999999972E-002
9.35640713965837040E-006
```

```
 each vp            2   1.0192864644000026        9.1611549259999965
0.0000000000000000        10260.493517119996        2.0851864644000022
2.77960088488264298E-004
 each vs            2  0.34646076779999940        4.1727825370000007
0.0000000000000000        4673.5164414400006       0.69738276779999930
1.49220137885108670E-004
```

inter.job

This shell script must be executed to generate the modes for the layered models that constitute the 3D structure.

```
#!/bin/sh
echo "obtaining str files through p5r"
#rm bacb*str
p5r.out
zip -q -m struc_gra.zip *xy *gplot
echo "calculating Rayleigh spectra"
ray
zip -q -m Rayleigh_gra.zip *pspr *gspr
#rm *r03 *r04 *yan
echo "checking Rayleigh spectra files"
ls *.spr > checksp.inp
checksp.out
mv checksp.pri checksp.pri.ray
```

lame.chk

```
pas           1   4.3766799999999995       2.6220700000000003       8.7533599999999989       3.4238599999999990
pas           2   5.3276517629999987       4.1727825370000007       12.558776474000005       9.1611549259999965
pas           3   6.6469999999999985       6.6469999999999985       16.514000000000003       16.514000000000003
pas           4   12.695999999999998       12.695999999999998       16.944000000000006       16.944000000000006
pas           5   30.818699999999996       30.818699999999996       33.563800000000008       33.563800000000008
pas           6   34.912500000000001       34.912500000000001       39.729000000000013       39.729000000000013
pas           7   34.912500000000001       34.912500000000001       39.729000000000013       39.729000000000013
pas           8   36.043149999999997       36.043149999999997       37.852100000000014       37.852100000000014
pas           9   39.290300000000002       39.290300000000002       42.676899999999996       42.676899999999996
pas          10   46.399999999999999       46.399999999999999       49.299999999999997       49.299999999999997
pas          11   57.318999999999996       57.318999999999996       59.737000000000009       59.737000000000009
pas          12   67.837500000000006       67.837500000000006       84.118499999999997       84.118499999999997
pas          13   68.139335000000003       68.139335000000003       86.236705000000001       86.236705000000001
pas          14   69.667663999999988       69.667663999999988       92.757797000000039       92.757797000000039
pas          15   72.758947999999990       72.758947999999990       102.37423600000005       102.37423600000005
pas          16   78.410591999999994       78.410591999999994       109.18856799999998       109.18856799999998
pas          17   85.151449999999997       85.151449999999997       114.50747799999998       114.50747799999998
pas          18   93.731904000000000       93.731904000000000       121.47221700000003       121.47221700000003
pas          19   103.35937500000000       103.35937500000000       130.93545375000008       130.93545375000008
pas          20   104.85723419999999       104.85723419999999       133.23553160000000       133.23553160000000
pas          21   106.39878864999999       106.39878864999999       135.83630830000001       135.83630830000001
pas          22   107.90363999999998       107.90363999999998       138.09695640000001       138.09695640000001
pas          23   110.32833875000001       110.32833875000001       141.55743770000007       141.55743770000007
pas          24   112.91187599999999       112.91187599999999       145.12384800000009       145.12384800000009
pas          25   115.48817999999999       115.48817999999999       148.75362044999997       148.75362044999997
pas          26   118.09922490000000       118.09922490000000       152.43930380000000       152.43930380000000
pas          27   122.01881999999999       122.01881999999999       157.84996080000002       157.84996080000002
pas          28   129.40537699999999       129.40537699999999       167.38007899999997       167.38007899999997
pas          29   136.29667000000001       136.29667000000001       173.02597999999995       173.02597999999995
pas          30   143.62184460000000       143.62184460000000       164.44334579999992       164.44334579999992
pas          31   150.57900000000001       150.57900000000001       183.20308160000013       183.20308160000013
pas          32   156.12502500000002       156.12502500000002       190.48258088999998       190.48258088999998
pas          33   161.46231711999997       161.46231711999997       197.60066144000010       197.60066144000010
pas          34   166.63223199999999       166.63223199999999       203.98929850000007       203.98929850000007
pas          35   171.94114700000003       171.94114700000003       209.83403799999988       209.83403799999988
pas          36   173.82812500000000       173.82812500000000       212.94663320000004       212.94663320000004
pas          37   176.00904375000002       176.00904375000002       215.42735432999987       215.42735432999987
pas          38   178.43494049999998       178.43494049999998       218.75256900000008       218.75256900000008
pas          39   181.05360852000001       181.05360852000001       221.45870796000000       221.45870796000000
pas          40   182.88997999999998       182.88997999999998       224.70841119999994       224.70841119999994
pas          41   185.25916800000002       185.25916800000002       228.25417447999985       228.25417447999985
pas          42   186.94687499999998       186.94687499999998       231.91969960000011       231.91969960000011
pas          43   189.05262299999998       189.05262299999998       236.13057412000012       236.13057412000012
pas          44   191.17195650000002       191.17195650000002       240.38866300000001       240.38866300000001
pas          45   192.95284788000001       192.95284788000001       243.83510423999999       243.83510423999999
```

p5r.par

This file tells program *p5r.out*, called by inter.job, how to prepare the `.str` files required by programs *lov* and *ray* to generate the modes (`.spl` and `.spr` files)

```
Parameters file for program p5r
0                   reference structure (0 = none)
   1.000            max frequency (10 Hz or 1 Hz or 0.1 Hz)
   6.420            min velocity for halfspace (1Hz=6.42,10Hz=4.50)
   0.000            max depth (0=use vel; x=km,if in channel stay above)
1                   split more at physical interfaces (0=no, 1=YES)
1                   add num gradient to num layers (0=no, 1=YES)
1                   take care of low-velocity channels (0=no, 1=YES)
   2.000            largest Vs to split using wavelength (sugg. 2.0)
   1.000            wavelength correction factor (suggested 1.0)
   0.000            max depth for plotting (0=all)
```

```
bout.stp
bin.stp
bacb001.stp
bacb002.stp
```

inter.job

This script generates the modes for the layered structures that build ip the 3D model.

```
#!/bin/sh
echo "obtaining str files through p5r"
#rm bacb*str
p5r.out
zip -q -m struc_gra.zip *xy *gplot
echo "calculating Rayleigh spectra"
ray
zip -q -m Rayleigh_gra.zip *pspr *gspr
#rm *r03 *r04 *yan
echo "checking Rayleigh spectra files"
ls *.spr > checksp.inp
checksp.out
mv checksp.pri checksp.pri.ray
```

Input files

This script does not need any user-prepared input file other than the `.stp` files already required by *`intergenstru.out`*.

Output files

.spl and .spr

Of all the output files generated by the script, what really matter are files `.spl` or `.spr` that contain Love or Rayleigh modes respectively.

inp3D.out

This program generates, for each mode-frequency combination, the information on phase velocity, phase attenuation, and an "interpolated velocity" in each grid point.

Input files

inp3D.par

This file describes the size of the grid and contains the association between the grid knots and the modes generated for the structures that build up the 3D model.

```
1.0 Frequency (Hz)
4 4 (Columns, Rows)
0. 0. 15. 15. (km) origin coords (x y) and step (dx, dy)
1 1 bout.spr
1 2 bacb001.spr
1 3 bacb002.spr
1 4 bin.spr
2 1 bacb001.spr
2 2 bacb001.spr
2 3 bacb002.spr
2 4 bacb002.spr
3 1 bacb002.spr
3 2 bacb002.spr
3 3 bacb001.spr
3 4 bacb001.spr
4 1 bin.spr
4 2 bacb002.spr
4 3 bacb001.spr
4 4 bout.spr
```

tau3D.par

This file contains the configuration parameters needed to describe the path along which the seismogram will be generated.

```
test 3D software
0.01d+00     (km)             :error distance true station point-calculated one
0.02d+00     (adimensional)   :step of the runge-kutta integration (take greater than
precision)
0.01d-00     (adimensional)   :precision of the runge-kutta integration
07.5d+00  7.5d+00   (km)      :epicentral (X,Y) coordinates (0,0=lower left)
37.5d+00  37.5d+00            :receiver (X,Y) coordinates
0.001                         :step for numerical differentiation
0.0
0.0000000000000000D+01        :(not used)
0                             :interpolation (0-9) (not tested)
```

Output files

inp3d.pri

This file contains a summary of the program execution

```
the grid has a total of          16  points, distributed
 in           4   columns and           4  rows
 column:           1 , row:           1 ,  reading spectra: bout.spr
 spectra is correct
 column:           1 , row:           2 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           1 , row:           3 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           1 , row:           4 ,  reading spectra: bin.spr
 spectra is correct
 column:           2 , row:           1 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           2 , row:           2 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           2 , row:           3 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           2 , row:           4 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           3 , row:           1 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           3 , row:           2 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           3 , row:           3 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           3 , row:           4 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           4 , row:           1 ,  reading spectra: bin.spr
 spectra is correct
 column:           4 , row:           2 ,  reading spectra: bacb002.spr
 spectra is correct
 column:           4 , row:           3 ,  reading spectra: bacb001.spr
 spectra is correct
 column:           4 , row:           4 ,  reading spectra: bout.spr
 spectra is correct
```

tau3D.inp

This file contains for each mode-frequency combination, the information on phase velocity, phase attenuation, and an "interpolated velocity" in each grid point.

```
  209                          :minimum number of modes present in structures
    4    4
   0.0000000000000000        0.0000000000000000        15.000000000000000
15.000000000000000
  0.4453746025324036D+01  0.4187685899795244D-03  0.5894065645434114D+01
0.5000000000000000D-02    2    1    1    1
  0.4453718955015256D+01  0.4187816751569780D-03  0.5894065645434114D+01
0.5000000000000000D-02    2    1    2    1
  0.4453695943446832D+01  0.4187947012582767D-03  0.5894065645434114D+01
0.5000000000000000D-02    2    1    3    1
  0.4453675624502267D+01  0.4188083926996787D-03  0.5894065645434114D+01
0.5000000000000000D-02    2    1    4    1
```

```
...
...

  0.6284189784691278D+01  0.3404851189037924D-03  0.6273093484637999D+01
0.1000000000000000D+01  201  209    4    3
  0.6282877461403591D+01  0.3243296407324329D-03  0.6272171495391788D+01
0.1000000000000000D+01  201  209    1    4
  0.6283507455189661D+01  0.3323004766970506D-03  0.6272562519068075D+01
0.1000000000000000D+01  201  209    2    4
  0.6284189784691278D+01  0.3404851189037924D-03  0.6273093484637999D+01
0.1000000000000000D+01  201  209    3    4
  0.6284876506892304D+01  0.3474714106709050D-03  0.6273749642907594D+01
0.1000000000000000D+01  201  209    4    4
```

detstru.out

This program determines the structures positioned at the source and immediately before the receiver position.

Input files

inp3D.par

See description above for program inp3D.out)

tau3D.par

See description above (for program inp3D.out)

Output files

tau_rec.pri

Contains the name of the modes file associated with the structure located immediately before the receiver position.

```
bacb001.spr                    : structure immediately before the receiver
```

tau_src.pri

Contains the name of the modes file associated with the structure located at the source position.

```
bout.spr                       : structure assigned to source
```

modes2daf01.out

This program generates for each .spl or .spr files, which can only be read sequentially, a file whose records can be accessed randomly (`.sdl` or `.sdr` for Love and Rayleigh modes respectively), and an index file (`.sil` or `.sir` for Love and Rayleigh modes respectively) that helps pointing to the desired frequency of a given mode.

Input files

.spl, .spr

See the 1D modal summation manuals fo a description of these files

Output files

.sdl, .sil, .sdr, .sil

These output files are not human-readable.

tauj2D.out

Performs the two-point dynamic ray tracing at a plane surface given the coordinates of source and receiver, velocity and attenuation in the grid points, initial grid points x0,y0, steps in x and y, number of points along x and y.

Input files

tau.par

This file contains the configuration parameters needed to describe the path along which the seismogram will be generated.

```
--------- input files --------|-------------------
bacb_r_.tau                   with structures and distances
none                          with cumul. travel time ('none' for nothing)
--------- output files -------|-------------------
0                             output file for continuation (0 - no,1 - yes)
none                          name for output files ('none' means default)
--------- control parameters -|-------------------
0                             interpolation
0                             receivers in smooth varying structure (nll)
1                             receivers in last flat structure (nre)
--------- if follows a variable number of lines (free format) ------------
nll lines with: distance boundary-receiver in each structure & ordinal
                number of structure in file nameinp.e2
nre lines with: distance boundary receiver & 0
-------------------------------------------------------------------------
21.0  0
warning: all the commentaries have to be put after column 30
```

bacb_r_.tau

See description above (generated by *intergenstru.out*, see description there)

Output files

.wkbjr

This file contains the arrival time and geometrical spreading for the path. It will be used for the computation of synthetic seismograms, and will be referenced in file `rwkbj.cnt`.

```
    0  : receivers in smooth 2d structure (nll)
    1  : receivers in flat 1d structure   (nre)
bin.spr                       :tarjet structure
 0.2840568264758417D+00       :cummulative distance
  209                         :number of modes present
n(fr) mode  cummulati travel time     cummulative "J"       cummulative t1
cummulative ate
    2    1 0.6377984139153041D-01 0.1265106323708902D+01 0.4819369914820829D-01
0.1189596724100617D-03
    2    2 0.4522176050376978D-01 0.1784279952144298D+01 0.5056784057958994D-01
0.5402422787761485D-04
    3    1 0.6955881653736272D-01 0.1160000769173743D+01 0.6377984139153041D-01
0.1222011640505275D-03
    3    2 0.5169903227733809D-01 0.1560730967549000D+01 0.4522176050376978D-01
0.1010522459224674D-03
    3    3 0.4488841274560022D-01 0.1797530269667767D+01 0.4796025397505499D-01
0.5985918622502268D-04
    4    1 0.7103696466969799D-01 0.1135863294499317D+01 0.6955881653736272D-01
0.1304233674298768D-03
    4    2 0.5595960958331761D-01 0.1441902137422723D+01 0.5169903227733809D-01
0.1095978967493687D-03
    4    3 0.4954769253710407D-01 0.1628497242474124D+01 0.4488841274560022D-01
0.1027415246303567D-03

...
```

```
...

0.9239201684287831D-04
  201  205 0.4545683756644273D-01 0.1775052673448672D+01 0.4539268175268697D-01
0.8208949336118880D-04
  201  206 0.4539106656419515D-01 0.1777624710731615D+01 0.4532207434177265D-01
0.9395380192270530D-04
  201  207 0.4532309766576759D-01 0.1780290531865677D+01 0.4526194863341680D-01
0.9236608542607785D-04
  201  208 0.4526646743903445D-01 0.1782517741097911D+01 0.4519431094736516D-01
0.8413500286763334D-04
  201  209 0.4520420831521628D-01 0.1784972782717142D+01 0.4528337573195908D-01
0.9550805950913916D-04
   -1    0    0    0    0    0    0
 0.2100000000000000D+02       :distance boundary-receiver
```

tau.pri

This file contains a summary of the program execution.

```
 receivers in smooth varying structure: nll=           0
 receivers in final flat structure:     nre=           1
 nre=           1
   21.000000000000000               0
 reading structures in file: bacb_r_.tau                  total:           4
 working with structure: bout.spr                        length:
4.7342804412640292E-002
      cummulative distance:  4.7342804412640292E-002  <--
 working with structure: bacb001.spr                     length:
9.4685608825280584E-002
      cummulative distance:  0.14202841323792087       <--
 working with structure: bacb002.spr                     length:
9.4685608825280584E-002
      cummulative distance:  0.23671402206320147       <--
 working with structure: bin.spr                         length:
4.7342804412640292E-002
      cummulative distance:  0.28405682647584174       <--

 warning ---> important information <-- warning
 input file with structures and distances list: bacb_r_.tau
 no previous run of program was considered
 - no continuation file was generated
 information for a run of ?wkbj programs was saved
 in file: bacb_r_.wkbjr
 --> it corresponds to parameters until reaching:
 - last structure in file: bacb_r_.tau
   with receivers distance:
   21.000000000000000
 - checking information in files tau.chk and tau.war
```

raytrace3D.out

Performs the two-point dynamic ray tracing at a plane surface given the coordinates of source and receiver, velocity and attenuation in the grid points, initial grid points x0,y0, steps in x and y, number of points along x and y.

Input files

tau3d.par

See description above (for program inp3D.out)

tau3d.inp

See description above (for program inp3D.out)

tau_rec.pri

See description above (for program detstru.out)

Output files

.3wkbjr

This file contains the arrival time and geometrical spreading for the path. It will be used for the computation of synthetic seismograms, and will be referenced in file `rwkbj.cnt`.

```
    1  : receivers in smooth 2d structure (nll)
    0  : receivers in flat 1d structure   (nre)
 parameters from tau3D.par
 epdist=  1.0000000000000002E-002  deltaz=   0.0000000000000000
 epicentre coordinates in km:   7.5000000000000000        7.5000000000000000
 receiver coordinates in km:   37.500000000000000        37.500000000000000
bacb001.spr
 0.4242640687119285D+02
  209
n(fr) mode        travel time            "j*a1"            cummulative t1
ate
    2    1 0.9526068683242618D+01 0.1889596400462976D+03 0.0000000000000000D+00
0.1776747071724561D-01
    2    2 0.6754272456881397D+01 0.2664973018881491D+03 0.0000000000000000D+00
0.8069013647496282D-02
    3    1 0.1038917031097587D+02 0.1732684989466993D+03 0.0000000000000000D+00
0.1825130732693464D-01
    3    2 0.7721711095793271D+01 0.2331079403624277D+03 0.0000000000000000D+00
0.1509304930300875D-01

...
...

  201  203 0.6811159453283921D+01 0.2644783531940946D+03 0.0000000000000000D+00
0.1605165032039709D-01
  201  204 0.6798992142454232D+01 0.2648587841824463D+03 0.0000000000000000D+00
0.1380941560907671D-01
  201  205 0.6789183906391870D+01 0.2652109271077416D+03 0.0000000000000000D+00
0.1223515396657849D-01
  201  206 0.6779247791548491D+01 0.2657176977062145D+03 0.0000000000000000D+00
0.1399347598257155D-01
  201  207 0.6769088897507189D+01 0.2661275636119988D+03 0.0000000000000000D+00
0.1377520214789115D-01
  201  208 0.6760712581058400D+01 0.2664161418453272D+03 0.0000000000000000D+00
0.1265098365814957D-01
  201  209 0.6751384496955128D+01 0.2667417898541715D+03 0.0000000000000000D+00
0.1440003590032864D-01
   -1    0    0    0    0    0    0
 0.0000000000000000D+00       :distance boundary-receiver
```

raytrace3D.pri

This file contains a summary of the program execution.

```
   coordinates of the station:  0.38D+02  0.38D+02
  distance            : 0.424D+02   travel time in s:  0.95D+01
   azimuth    0.450D+02
   azimuth    0.451D+02
   azimuth    0.449D+02
   coordinates of the station:  0.38D+02  0.38D+02
  distance            : 0.424D+02   travel time in s:  0.68D+01
   azimuth    0.450D+02
   azimuth    0.451D+02
   azimuth    0.449D+02
   coordinates of the station:  0.38D+02  0.38D+02
  distance            : 0.424D+02   travel time in s:  0.10D+02
   azimuth    0.450D+02
   azimuth    0.451D+02
   azimuth    0.449D+02

...
...

   coordinates of the station:  0.38D+02  0.38D+02
  distance            : 0.424D+02   travel time in s:  0.68D+01
   azimuth    0.450D+02
   azimuth    0.451D+02
   azimuth    0.449D+02
   coordinates of the station:  0.38D+02  0.38D+02
  distance            : 0.424D+02   travel time in s:  0.68D+01
   azimuth    0.450D+02
```

```
   azimuth    0.451D+02
   azimuth    0.449D+02
```

tau3D.pri

This file contains for each mode and frequency, the travel time, the value of j and ate.

```
n(fr) mode        travel time            "j"                          ate
    2    1 0.9526068683242618D+01 0.4242712515978045D+02 0.1776747071724561D-01
    2    2 0.6754272456881397D+01 0.4242632301949480D+02 0.8069013647496282D-02
    3    1 0.1038917031097587D+02 0.4242830798792432D+02 0.1825130732693464D-01
    3    2 0.7721711095793271D+01 0.4242625044090072D+02 0.1509304930300875D-01
    3    3 0.6704484280336588D+01 0.4242630682263703D+02 0.8940538899013861D-02
    4    1 0.1060990350320397D+02 0.4243138778611604D+02 0.1947899899633292D-01
    4    2 0.8358064432127890D+01 0.4242639921225832D+02 0.1636940362596348D-01
    4    3 0.7400390830714501D+01 0.4242611875176972D+02 0.1534537881368020D-01
    4    4 0.6721631438751261D+01 0.4242620312108993D+02 0.1077513871882297D-01

...
...

  201  201 0.6839041940170040D+01 0.4244783148320265D+02 0.1635189414262803D-01
  201  202 0.6823657380724663D+01 0.4245397051411815D+02 0.1712291368552721D-01
  201  203 0.6811159453283921D+01 0.4245235446359364D+02 0.1605165032039709D-01
  201  204 0.6798992142454232D+01 0.4244024532934674D+02 0.1380941560907671D-01
  201  205 0.6789183906391870D+01 0.4243662140850912D+02 0.1223515396657849D-01
  201  206 0.6779247791548491D+01 0.4245392887072920D+02 0.1399347598257155D-01
  201  207 0.6769088897507189D+01 0.4245536158235114D+02 0.1377520214789115D-01
  201  208 0.6760712581058400D+01 0.4244949376484588D+02 0.1265098365814957D-01
  201  209 0.6751384496955128D+01 0.4244185061737480D+02 0.1440003590032864D-01
```

rwkbj2D.out

This program generates the synthetic seismograms for the 3D model

Input

rwkbj.box

This file contains the parameterization of the source properties

```
 I N P U T   P A R A M E T E R S   F O R    1  S E I S M O G R A M (S)
001*****************************************************************************
  SEISMOGRAM  NAME                 :       uno       (7 ALPHANUMERICAL CHAR.)
 G E N E R A L  P A R A M E T E R S        0
  SEISMOGRAM TYPE                  :         1       (1=DISPL.,2=VEL.,3=ACCEL.)
  INTERPOLATION                    :         0       (0=NO,9=YES)
  GROUND MOTION COMPONENT          :         1       (1=R,2=V,3=T;4=N,5=W)
  RECEIVER DEPTH                   : 0.000000000E+00 (KM)
  NO. OF FIRST MODE TO BE USED     :         0       (ALL=0)
  NO. OF LAST MODE TO BE USED      :         0       (ALL=0)
  INPUT GROUND MOTION (FIXED TO 0):         0       (COMPUTED=0, SET IN PROGRAM)
  INPUT EIGENFUNCTIONS             :         0       (COMPUTED=0, READ IN=1)
  MAXIMUM FREQUENCY                :         1.      ( 1 OR 10 HZ )
  SPECTRUM FREQUENCY INTERVAL      :  .005000000E+00 (.005 FOR 1HZ, .05 FOR 10HZ)
  NUMBER OF FREQUENCY POINTS       :       201       (FIXED TEMPORARILY)
  NUMBER OF TIME SERIES POINTS     :      4096       (1024,2048,4096,8192)
 S O U R C E  P A R A M E T E R S
  SOURCE DEPTH                     :  .100000000E+02 (KM DEEP)
  ANGLE STRIKE-RECEIVER            :  .060000000E+03 (DEGREES)
  FAULT DIP                        :  .900000000E+02 (DEGREES)
  RAKE (WITH RESPECT TO STRIKE)    :  .600000000E+02 (DEGREES)
  FORCE SYSTEM                     :         1       (1=D-C,2=SINGLE,3=DIPOLAR)
                                                      4=S-C,5=P.EXPL,6=CAVITY EXP
  TIME FUNCTION                    :         1       (0=DELTA,1=STEP)
  SOURCE DURATION                  :  .000000000E+01 (SECONDS)
  DURATION SHAPE FUNCTION          :         0       (0=INS,1=D1,2=D2,3=PARZ,
                                                      4=K-G,5=H-K)
  SOURCE FINITENESS  (FIXED TO 0) :         0       (POINT=0,UNIL.=1,BILAT.=2)
  RUPTURE VEL./SOURCE S-WAVE VEL. :  .000000000E+00
  ALONG-STRIKE FAULT LENGHT        :  .000000000E+01 (KM)
  ANTI-STRIKE FAULT LENGHT         :  .000000000E+01 (KM)
 E X T R A  P A R A M E T E R S
  EMPTY1                           : 0.000000000E+00
  EMPTY2                           : 0.000000000E+00
  EMPTY3                           : 0.000000000E+00
```

```
  EMPTY4                          : 0.000000000E+00
  EMPTY5                          : 0.450000000E+01
```

rwkbj.cnt

This file describes the I/O filenames chosen by the user for the execution. The user must define the distance in km from the source to the heterogeneous zone.

```
----------------------|-----------------------------------------------
rwkbj.box               filename with input parameters (unit7)
seis2dw.rad             filename with output seismograms (unit2)
bout.sdr                source structure spectrum
bout.sir                spectral information for source spectrum
21.                     distance from source to wkbj region beginning
bacb_r_.wkbjr           output of program raytrace3D
----------------------|-----------------------------------------------
warning: all the comentaries have to be after column 25
Note: The control of the program is transferd to the file "output of
      program tau", where there are specified structures and receivers'
      position
```

Output

The main output we are interested in is the seismogram file.

seis2dw.rad

The seismogram(s) generated.

```
 I N P U T   P A R A M E T E R S   F O R    1  S E I S M O G R A M (S)
001*****************************************************************************
  SEISMOGRAM  NAME               :       uno       (7 ALPHANUMERICAL CHAR.)
 G E N E R A L  P A R A M E T E R S
  SEISMOGRAM TYPE                :         1       (1=DISPL.,2=VEL.,3=ACCEL.)
  INTERPOLATION                  :         0       (0=NO,9=YES)
  GROUND MOTION COMPONENT        :         1       (1=R,2=V,3=T;4=N,5=W)
  RECEIVER DEPTH                 : 0.000000000E+00 (KM)
  NO. OF FIRST MODE TO BE USED   :         1       (ALL=0)
  NO. OF LAST MODE TO BE USED    :       209       (ALL=0)
  INPUT GROUND MOTION (FIXED TO 0):         0       (COMPUTED=0, SET IN PROGRAM)
  INPUT EIGENFUNCTIONS           :         0       (COMPUTED=0, READ IN=1)
  MAXIMUM FREQUENCY              : 0.100000000E+01 ( 1 OR 10 HZ )
  SPECTRUM FREQUENCY INTERVAL    : 0.500000000E-02 (.005 FOR 1HZ, .05 FOR 10HZ)
  NUMBER OF FREQUENCY POINTS     :       201       (FIXED TEMPORARILY)
  NUMBER OF TIME SERIES POINTS   :      4096       (1024,2048,4096,8192)
 S O U R C E  P A R A M E T E R S
  total distance (computed)      : 0.424940568E+02 (km)
  SOURCE DEPTH                   : 0.100000000E+02 (KM DEEP)
  ANGLE STRIKE-RECEIVER          : 0.600000000E+02 (DEGREES)
  FAULT DIP                      : 0.900000000E+02 (DEGREES)
  RAKE (WITH RESPECT TO STRIKE)  : 0.600000000E+02 (DEGREES)
  FORCE SYSTEM                   :         1       (1=D-C,2=SINGLE,3=DIPOLAR)
                                                    4=s-c,5=p.expl,6=cavity exp
  TIME FUNCTION                  :         1       (0=DELTA,1=STEP)
  SOURCE DURATION                : 0.000000000E+00 (SECONDS)
  DURATION SHAPE FUNCTION        :         0       (0=INS,1=D1,2=D2,3=PARZ,
                                                    4=k-g,5=h-k,6=ma)
  SOURCE FINITENESS  (FIXED TO 0) :         0       (POINT=0,UNIL.=1,BILAT.=2)
  RUPTURE VEL./SOURCE S-WAVE VEL. : 0.000000000E+00
  ALONG-STRIKE FAULT LENGHT      : 0.000000000E+00 (KM)
  ANTI-STRIKE FAULT LENGHT       : 0.000000000E+00 (KM)
 i n s t r u m e n t response    :         0       (0=no,set to 0 in program)
  calibrat. type: (0=delta)      :         0       itycal
  magnification                  : 0.000000000E+00 xmag
  mechanical       (1)
   natural period                : 0.000000000E+00 t0(seconds)
   damping ratio                 : 0.000000000E+00 dampra
  electromagnetic  (2)
   pendulum period               : 0.000000000E+00 t1(seconds)
   galvanometer period           : 0.000000000E+00 t2(seconds)
   pendulum damping factor       : 0.000000000E+00 h1
   galvanometer damping factor   : 0.000000000E+00 h2
   instrument coupling factor    : 0.000000000E+00 sigsq
  geophone         (3)
   natural period                : 0.000000000E+00 tg(seconds)
   damping ratio                 : 0.000000000E+00 geodam
 g a u s s i a n roll-off filter  :         0       (0=no,set to 0 in program)
```

```
  max cut-off frequency           : 0.000000000E+00
  xpeak/(max cut-off freq)        : 0.000000000E+00 (between 0 and 1)
  amplitude at cut-off freq       : 0.000000000E+00 (between 0 and 1)
 E X T R A  P A R A M E T E R S
  EMPTY1                          : 0.000000000E+00
  EMPTY2                          : 0.000000000E+00
  EMPTY3                          : 0.000000000E+00
  EMPTY4                          : 0.000000000E+00
  EMPTY5                          : 0.450000000E+01
 name of 1. structure                        : bout.st
 number of layers in 1. structure            :  137
 number of summed rayleigh wave modes        :  209
 average source s-wave velocity (km/s)       : 0.350005000E+01
 *** fourier transform parameters ***
 actual frequency domain spectrum points     :  201
 spacing of frequency points (hz)            : 0.500000000E-02
 corresponding nyquist frequency (hz)        : 0.100000000E+01
 true time series sampling interval (s)      : 0.500000000E+00
 to increase the density of sampling in the
 time series zeros are added between the old
 and the new nyquist frequency (hz)          : 0.102400000E+02
 the resultant sampling interval (s)         : 0.488281250E-01

-0.174898E-06-0.414385E-06-0.631745E-06-0.808126E-06-0.927905E-06-0.980149E-06-0.95967
7E-06-0.867609E-06-0.711357E-06-0.504054E-06
 -0.263464E-06-0.104651E-07 0.232759E-06 0.444662E-06 0.606248E-06 0.702771E-06
0.725083E-06 0.670512E-06 0.543168E-06 0.353686E-06

0.118378E-06-0.142082E-06-0.404380E-06-0.644494E-06-0.839716E-06-0.970549E-06-0.102235
E-05-0.986584E-06-0.861508E-06-0.652380E-06
 -0.371027E-06-0.349101E-07 0.334266E-06 0.712262E-06 0.107418E-05 0.139639E-05
0.165823E-05 0.184351E-05 0.194159E-05 0.194790E-05


...
...

  0.128674E-05 0.130821E-05 0.125571E-05 0.113689E-05 0.964529E-06 0.755470E-06
0.529092E-06 0.305629E-06 0.104384E-06-0.579494E-07
 -0.168746E-06-0.220530E-06-0.211600E-06-0.146129E-06-0.337284E-07 0.111469E-06
0.272153E-06 0.429462E-06 0.564759E-06 0.661390E-06
  0.706271E-06 0.691148E-06 0.613428E-06 0.476488E-06 0.289442E-06 0.663717E-07
 ampl
          amax  = 0.223769719E-04          amin  =-0.287224679E-04 amaxa  =
0.287224679E-04 0.119127683E+01 0.561530898E+01
```

rwkbj3D.out

This program generates the synthetic seismograms for the 3D model

Input

rwkbj.box

This file contains the parameterization of the source properties

```
 I N P U T   P A R A M E T E R S   F O R    1  S E I S M O G R A M (S)
001*****************************************************************************
  SEISMOGRAM  NAME                :       uno       (7 ALPHANUMERICAL CHAR.)
 G E N E R A L  P A R A M E T E R S          0
  SEISMOGRAM TYPE                 :         1       (1=DISPL.,2=VEL.,3=ACCEL.)
  INTERPOLATION                   :         0       (0=NO,9=YES)
  GROUND MOTION COMPONENT         :         1       (1=R,2=V,3=T;4=N,5=W)
  RECEIVER DEPTH                  : 0.000000000E+00 (KM)
  NO. OF FIRST MODE TO BE USED    :         0       (ALL=0)
  NO. OF LAST MODE TO BE USED     :         0       (ALL=0)
  INPUT GROUND MOTION (FIXED TO 0):         0       (COMPUTED=0, SET IN PROGRAM)
  INPUT EIGENFUNCTIONS            :         0       (COMPUTED=0, READ IN=1)
  MAXIMUM FREQUENCY               :         1.      ( 1 OR 10 HZ )
  SPECTRUM FREQUENCY INTERVAL     :  .005000000E+00 (.005 FOR 1HZ, .05 FOR 10HZ)
  NUMBER OF FREQUENCY POINTS      :       201       (FIXED TEMPORARILY)
  NUMBER OF TIME SERIES POINTS    :      4096       (1024,2048,4096,8192)
 S O U R C E  P A R A M E T E R S
  SOURCE DEPTH                    :  .100000000E+02 (KM DEEP)
  ANGLE STRIKE-RECEIVER           :  .060000000E+03 (DEGREES)
```

```
  FAULT DIP                        :  .900000000E+02 (DEGREES)
  RAKE (WITH RESPECT TO STRIKE)    :  .600000000E+02 (DEGREES)
  FORCE SYSTEM                     :          1       (1=D-C,2=SINGLE,3=DIPOLAR)
                                                       4=S-C,5=P.EXPL,6=CAVITY EXP
  TIME FUNCTION                    :          1       (0=DELTA,1=STEP)
  SOURCE DURATION                  :  .000000000E+01 (SECONDS)
  DURATION SHAPE FUNCTION          :          0       (0=INS,1=D1,2=D2,3=PARZ,
                                                       4=K-G,5=H-K)
  SOURCE FINITENESS  (FIXED TO 0) :          0       (POINT=0,UNIL.=1,BILAT.=2)
  RUPTURE VEL./SOURCE S-WAVE VEL. :  .000000000E+00
  ALONG-STRIKE FAULT LENGHT        :  .000000000E+01 (KM)
  ANTI-STRIKE FAULT LENGHT         :  .000000000E+01 (KM)
 E X T R A  P A R A M E T E R S
  EMPTY1                           : 0.000000000E+00
  EMPTY2                           : 0.000000000E+00
  EMPTY3                           : 0.000000000E+00
  EMPTY4                           : 0.000000000E+00
  EMPTY5                           : 0.450000000E+01
```

rwkbj.cnt

This file describes the I/O filenames chosen by the user for the execution

```
-----------------------|-----------------------------------------------
rwkbj.box                filename with input parameters (unit7)
seis3d.rad               filename with output seismograms (unit2)
bout.sdr                 source structure spectrum
bout.sir                 spectral information for source spectrum
0.0                      distance from source to wkbj region beginning
bacb001.3wkbjr           output of program raytrace3D
-----------------------|-----------------------------------------------
warning: all the comentaries have to be after column 25
Note: The control of the program is transferd to the file "output of
      program tau", where there are specified structures and receivers'
      position
```

Output

The main output we are interested in is the seismogram file.

seis3d.rad

The seismogram(s) generated.

```
 I N P U T   P A R A M E T E R S   F O R    1  S E I S M O G R A M (S)
001*****************************************************************************
  SEISMOGRAM  NAME                 :       uno       (7 ALPHANUMERICAL CHAR.)
 G E N E R A L  P A R A M E T E R S
  SEISMOGRAM TYPE                  :         1       (1=DISPL.,2=VEL.,3=ACCEL.)
  INTERPOLATION                    :         0       (0=NO,9=YES)
  GROUND MOTION COMPONENT          :         1       (1=R,2=V,3=T;4=N,5=W)
  RECEIVER DEPTH                   : 0.000000000E+00 (KM)
  NO. OF FIRST MODE TO BE USED     :         1       (ALL=0)
  NO. OF LAST MODE TO BE USED      :       209       (ALL=0)
  INPUT GROUND MOTION (FIXED TO 0):         0       (COMPUTED=0, SET IN PROGRAM)
  INPUT EIGENFUNCTIONS             :         0       (COMPUTED=0, READ IN=1)
  MAXIMUM FREQUENCY                : 0.100000000E+01 ( 1 OR 10 HZ )
  SPECTRUM FREQUENCY INTERVAL      : 0.500000000E-02 (.005 FOR 1HZ, .05 FOR 10HZ)
  NUMBER OF FREQUENCY POINTS       :       201       (FIXED TEMPORARILY)
  NUMBER OF TIME SERIES POINTS     :      4096       (1024,2048,4096,8192)
 S O U R C E  P A R A M E T E R S
  total distance (computed)        : 0.424264069E+02 (km)
  SOURCE DEPTH                     : 0.100000000E+02 (KM DEEP)
  ANGLE STRIKE-RECEIVER            : 0.600000000E+02 (DEGREES)
  FAULT DIP                        : 0.900000000E+02 (DEGREES)
  RAKE (WITH RESPECT TO STRIKE)    : 0.600000000E+02 (DEGREES)
  FORCE SYSTEM                     :         1       (1=D-C,2=SINGLE,3=DIPOLAR)
                                                       4=s-c,5=p.expl,6=cavity exp
  TIME FUNCTION                    :         1       (0=DELTA,1=STEP)
  SOURCE DURATION                  : 0.000000000E+00 (SECONDS)
  DURATION SHAPE FUNCTION          :         0       (0=INS,1=D1,2=D2,3=PARZ,
                                                       4=k-g,5=h-k,6=ma)
  SOURCE FINITENESS  (FIXED TO 0) :         0       (POINT=0,UNIL.=1,BILAT.=2)
  RUPTURE VEL./SOURCE S-WAVE VEL. : 0.000000000E+00
  ALONG-STRIKE FAULT LENGHT        : 0.000000000E+00 (KM)
  ANTI-STRIKE FAULT LENGHT         : 0.000000000E+00 (KM)
 i n s t r u m e n t response     :         0       (0=no,set to 0 in program)
  calibrat. type: (0=delta)        :         0       itycal
```

```
 magnification                   : 0.000000000E+00 xmag
 mechanical       (1)
  natural period                 : 0.000000000E+00 t0(seconds)
  damping ratio                  : 0.000000000E+00 dampra
 electromagnetic  (2)
  pendulum period                : 0.000000000E+00 t1(seconds)
  galvanometer period            : 0.000000000E+00 t2(seconds)
  pendulum damping factor        : 0.000000000E+00 h1
  galvanometer damping factor    : 0.000000000E+00 h2
  instrument coupling factor     : 0.000000000E+00 sigsq
 geophone         (3)
  natural period                 : 0.000000000E+00 tg(seconds)
  damping ratio                  : 0.000000000E+00 geodam
g a u s s i a n roll-off filter  :         0       (0=no,set to 0 in program)
 max cut-off frequency           : 0.000000000E+00
 xpeak/(max cut-off freq)        : 0.000000000E+00 (between 0 and 1)
 amplitude at cut-off freq       : 0.000000000E+00 (between 0 and 1)
E X T R A  P A R A M E T E R S
 EMPTY1                          : 0.000000000E+00
 EMPTY2                          : 0.000000000E+00
 EMPTY3                          : 0.000000000E+00
 EMPTY4                          : 0.000000000E+00
 EMPTY5                          : 0.450000000E+01
name of 1. structure                      : bout.st
number of layers in 1. structure          :  137
number of summed rayleigh wave modes      :  209
average source s-wave velocity (km/s)     : 0.350005000E+01
*** fourier transform parameters ***
actual frequency domain spectrum points   :  201
spacing of frequency points (hz)          : 0.500000000E-02
corresponding nyquist frequency (hz)      : 0.100000000E+01
true time series sampling interval (s)    : 0.500000000E+00
to increase the density of sampling in the
time series zeros are added between the old
and the new nyquist frequency (hz)        : 0.102400000E+02
the resultant sampling interval (s)       : 0.488281250E-01
  0.544827E-06
0.266653E-06-0.431345E-07-0.373972E-06-0.711730E-06-0.103943E-05-0.133835E-05-0.158937
E-05-0.177455E-05-0.187876E-05

-0.189116E-05-0.180649E-05-0.162591E-05-0.135745E-05-0.101583E-05-0.621715E-06-0.20047
7E-06 0.219559E-06 0.609175E-06 0.940513E-06
  0.118931E-05 0.133697E-05 0.137221E-05 0.129220E-05 0.110311E-05 0.819839E-06
0.465138E-06 0.679973E-07-0.338476E-06-0.719590E-06

-0.104178E-05-0.127530E-05-0.139667E-05-0.139068E-05-0.125175E-05-0.984576E-06-0.60397
2E-06-0.133870E-06 0.394363E-06 0.944243E-06
  0.147690E-05 0.195400E-05 0.234068E-05 0.260819E-05 0.273607E-05 0.271368E-05
0.254097E-05 0.222846E-05 0.179632E-05 0.127283E-05

...
...


-0.132455E-05-0.122184E-05-0.106004E-05-0.849483E-06-0.602867E-06-0.334140E-06-0.57366
5E-07 0.214349E-06 0.469781E-06 0.700253E-06
  0.900007E-06 0.106626E-05 0.119894E-05 0.130015E-05 0.137346E-05 0.142305E-05
0.145285E-05 0.146581E-05 0.146330E-05 0.144480E-05
  0.140787E-05 0.134844E-05 0.126136E-05 0.114123E-05 0.983354E-06 0.784695E-06
 ampl
          amax  = 0.183030423E-04          amin  =-0.250794719E-04 amaxa  =
0.250794719E-04 0.119127683E+01 0.561530898E+01
```