Site Effects Assessment Using Ambient Excitations

SESAME

European Commission – Research General Directorate
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Final Report

WP09

FD code to generate noise synthetic

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List of Contents

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Summary

In the following we report the flowchart and the guide user of the Fortran95 Program Package NOISE, a program for numerical generation and simulation of seismic noise in 3D heterogeneous viscoelastic media. This program package consists of two programs: program RANSOURCE and program FDSIM. The whole program is presented in the attached CR ROM.

In the appendix, a set of canonical models for seismic noise simulations is described. The set of the canonical models will serve for extensive parametric study of synthetic seismic noise which will create a basis for deducing systematic features of the noise and decisive factors determining peak H/V and HT (VT) frequencies and corresponding amplitudes.

Chapter 1 : Flowcharts of the program package NOISE

During this first year, the Fortran95 Program Package NOISE for numerical generation and simulation of seismic noise in 3D heterogeneous viscoelastic media has been developed. The program package consists of two programs: program RANSOURCE and program FDSIM.

Program RANSOURCE is designed for random space-time generation of point sources of seismic noise. The output files serve as input files for the program FDSIM.

The algorithm of random noise generation assumes regular spatial distribution of potential point sources inside of a specified source volume. The spatial distribution is controlled by the prescribed minimum distance between two neighbour point sources, minimum distance between a point source and a receiver, and maximum distance between a point source and a receiver.

The temporal distribution of point sources is controlled by the prescribed minimum and maximum numbers of point sources acting at the same time.

For each generated position of a point source, a direction of acting single body force at the position, time function and maximum amplitude are randomly generated.

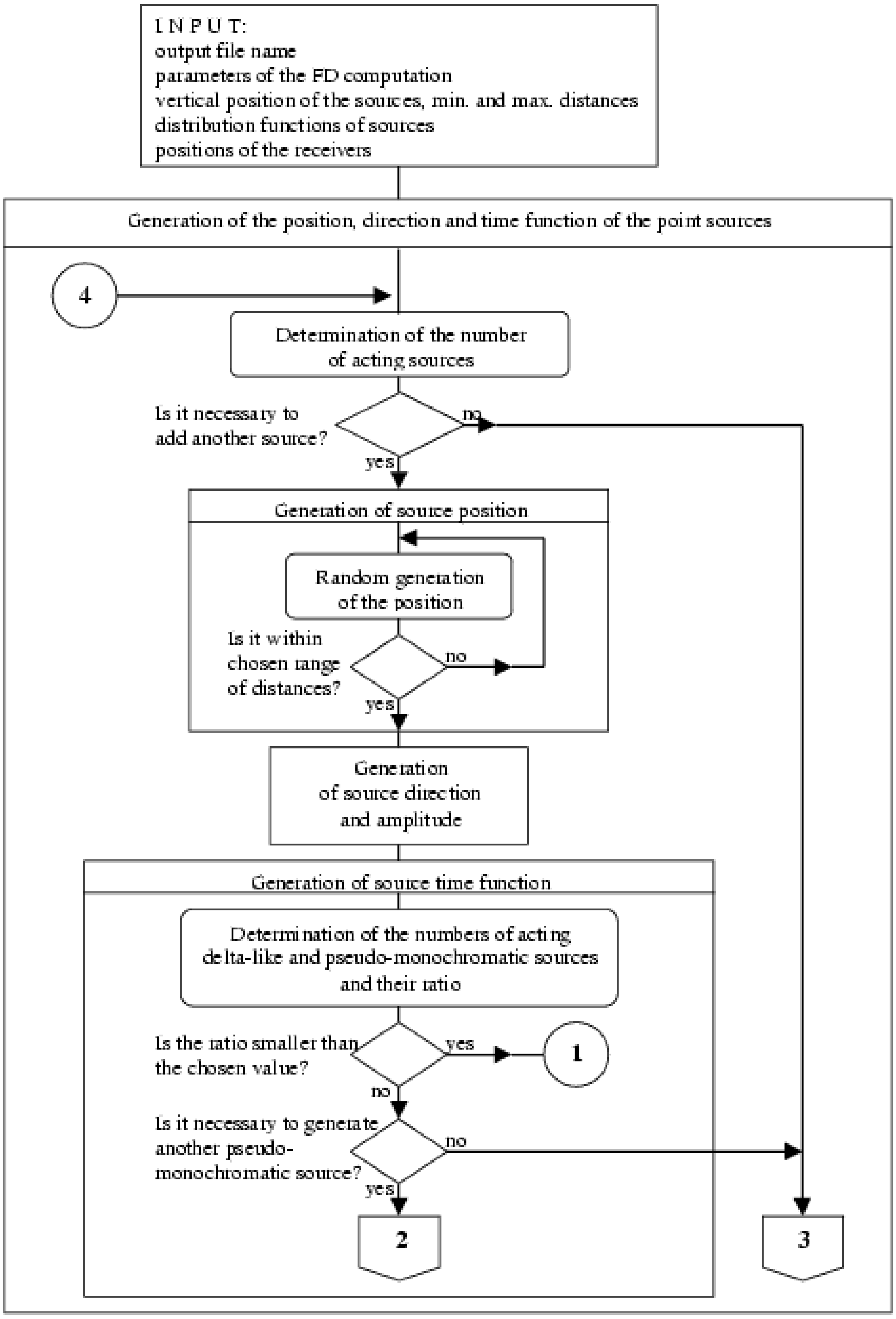
The time function is either delta-like signal or pseudo-monochromatic signal (a harmonic carrier with the Gaussian envelope). Spectrum of the delta-like signal is low-pass filtered in order to fit the prescribed frequency range. In the case of the pseudo-monochromatic signal, first its duration, then its predominant frequency are randomly generated.

The maximum amplitude of the signal is randomly generated from the interval (0,1> according to a chosen distribution.

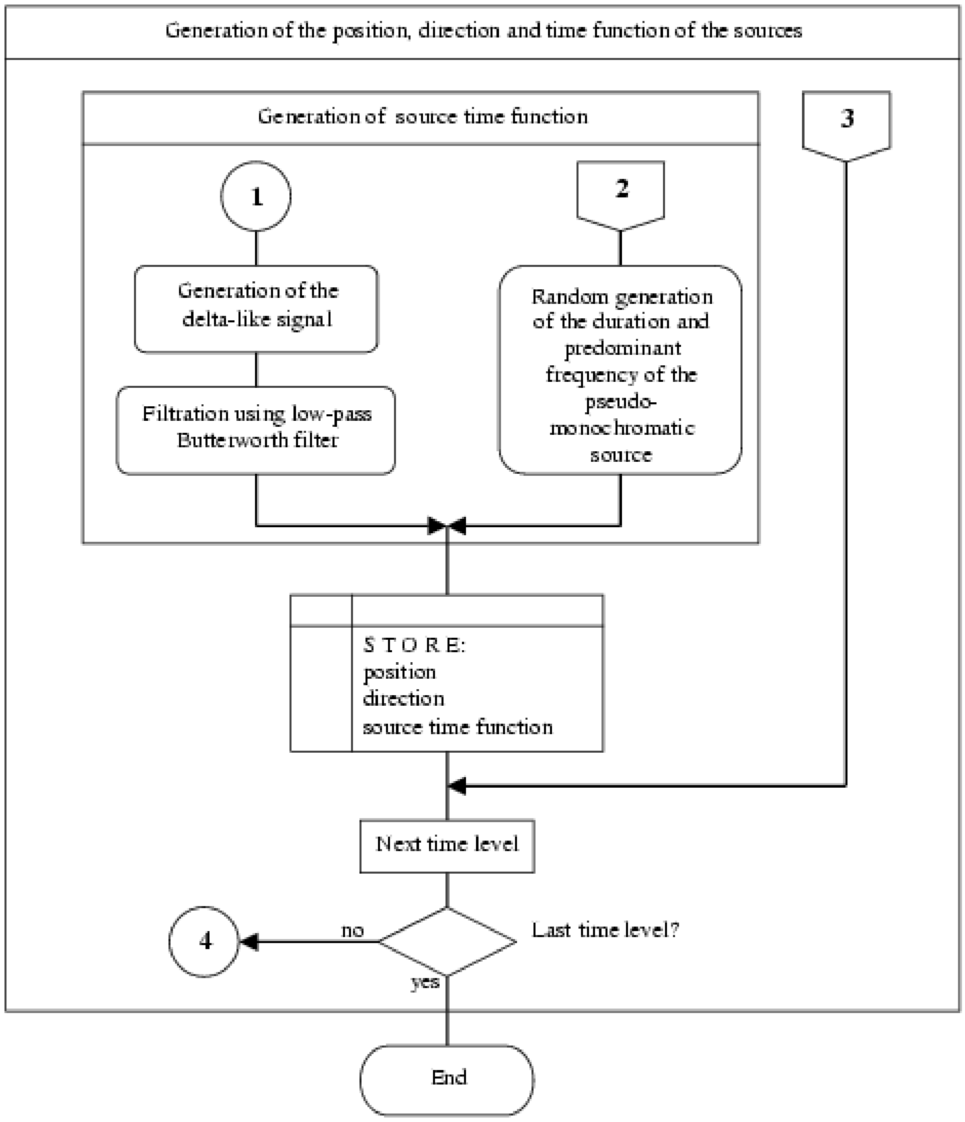
The program has to be run before the finite-difference simulation of the noise itself. The program generates two files for all delta-like sources and as many files as the number of generated pseudo-monochromatic sources. All the files serve as the input data files for the program FDSIM.

Pages 4 and 5: Flowchart of the program RANSOURCE.

RANSOURCE: *Flowchart of the program* 1



RANSOURCE: *Flowchart of the program* 2



Program FDSIM is designed for the finite-difference simulation of seismic wave propagation and seismic ground motion in a 3D surface heterogeneous viscoelastic structure with a planar free surface.

The computational algorithm is based on the explicit heterogeneous finite-difference scheme solving equations of motion in the heterogeneous viscoelastic medium with material discontinuities. The scheme is 4^{th}-order accurate in space and 2^{nd}-order accurate in time. The displacement-velocity-stress scheme is constructed on a staggered finite-difference grid.

The computational region is represented by a volume of a parallelepiped with the top side representing a planar free surface, and bottom, rear, front, left and right sides representing either non-reflecting boundaries or planes of symmetry. Different types of non-reflecting boundaries can be chosen on different sides of the computational region.

The discontinuous spatial grid is used to cover the computational region. The upper part of the grid has three times smaller grid spacing than the lower part. Each part itself is a uniform rectangular grid.

The rheology of the medium corresponds to the generalised Maxwell body. This makes possible to account both for spatially varying quality factors of the P and S waves and for arbitrary Q-omega law.

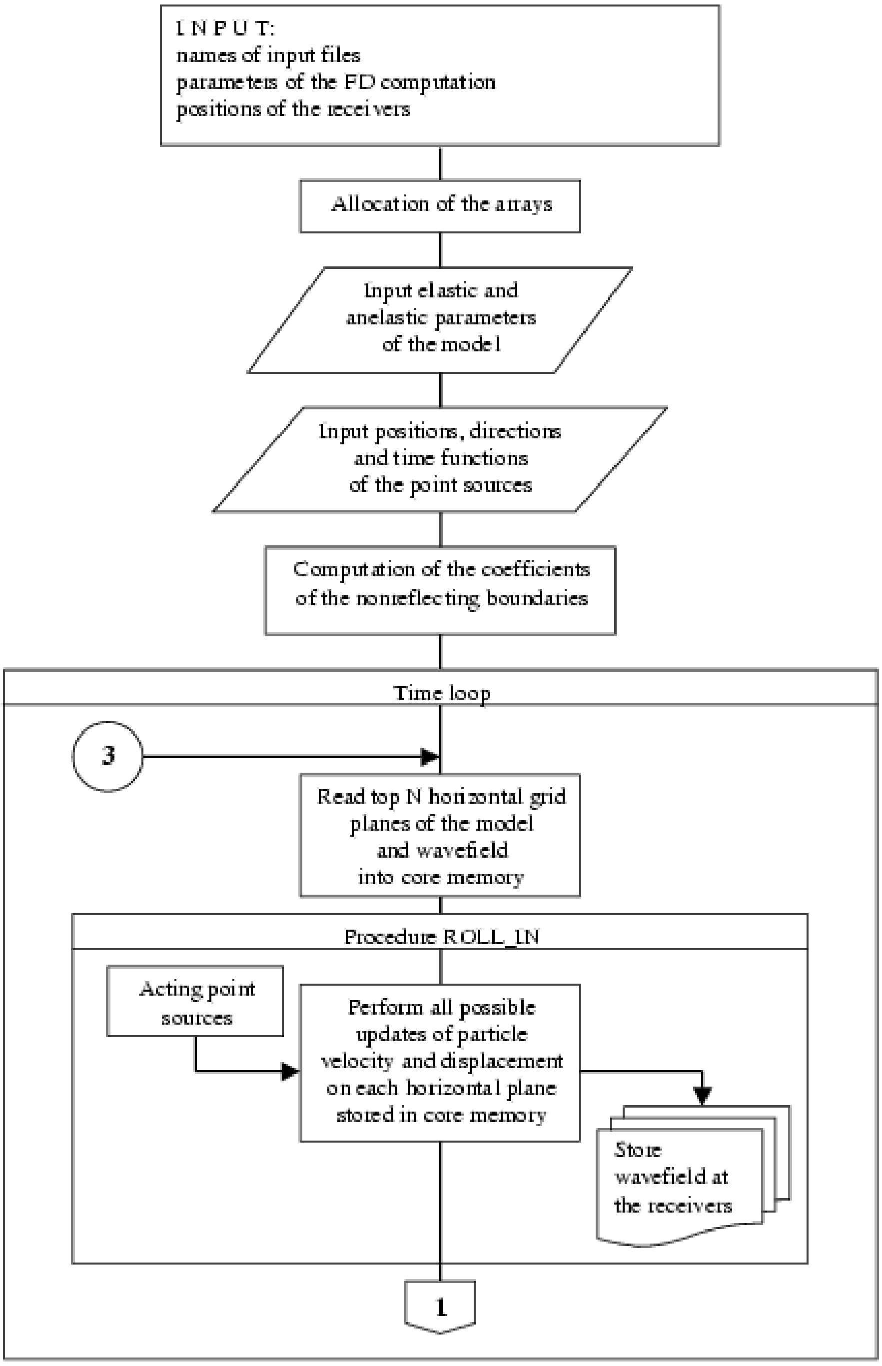
The wavefield is excited by a set of randomly generated point sources, each representing a single force acting in an arbitrary direction.

The core memory optimisation is applied in order to significantly reduce requirements of the computer's core memory.

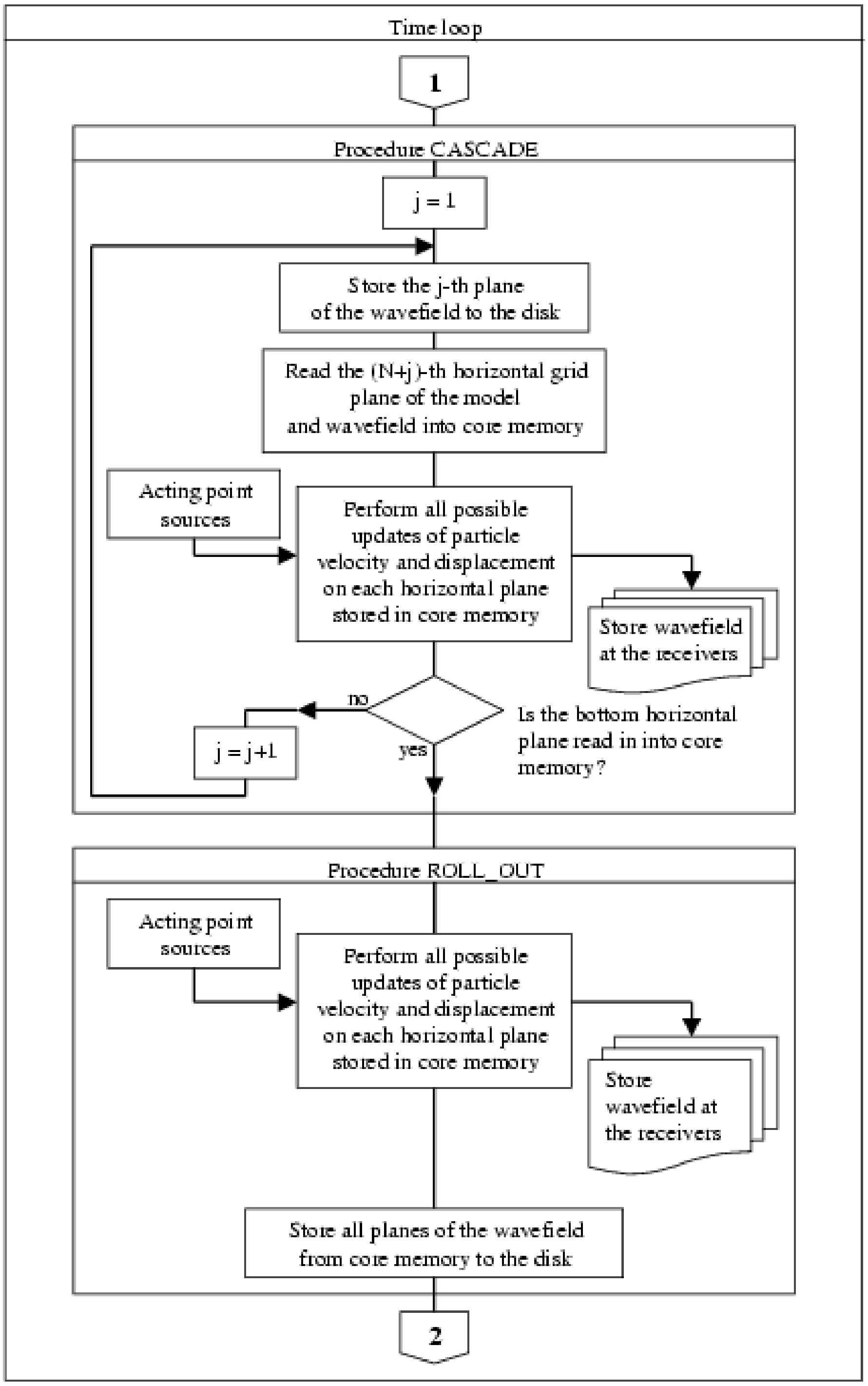
Pages 7, 8 and 9: Flowchart of the program FDSIM.

FDSIM:* *Flowchart of the program

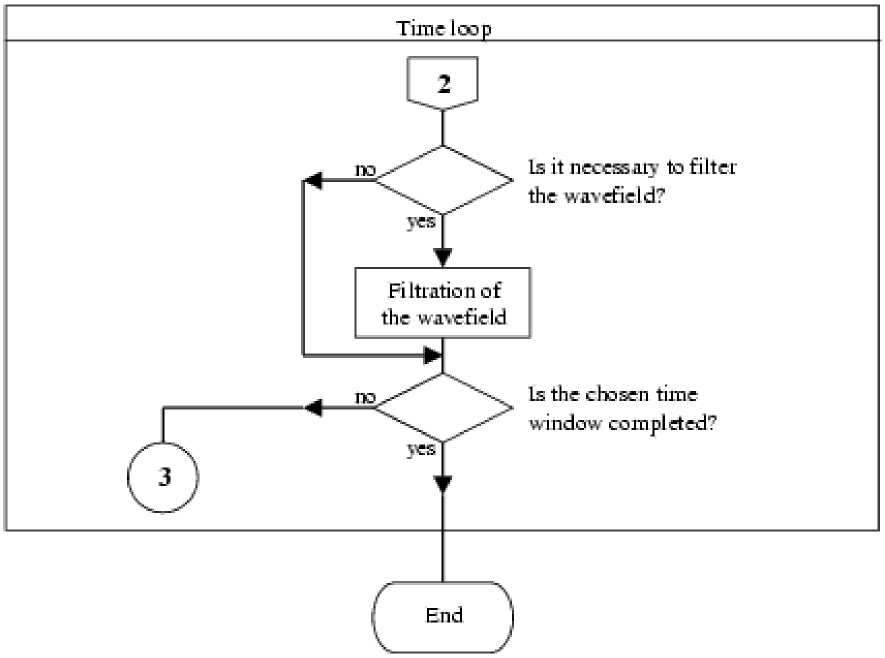
1



FDSIM: Flowchart of the program 2



FDSIM: Flowchart of the program 3



Chapter 2 : User Guide

```
================================================================================
================================================================================
|                                                                              |
|                              USER'S  GUIDE  TO                               |
|                                                                              |
|                                 ===========                                  |
|                                 N O I S E                                    |
|                                 ===========                                  |
|                                                                              |
|                        The Fortran95 Program Package                         |
|                   for Numerical Generation and Simulation                    |
|                              of Seismic Noise                                |
|                   in  3D Heterogeneous Viscoelastic Media                    |
|                                                                              |
|                                     by                                       |
|                                                                              |
|                      Jozef KRISTEK  &  Peter MOCZO                           |
|                                                                              |
|                        Bratislava, April 30, 2002                            |
================================================================================
================================================================================
```

Note: This is the first version of the program package. The version is functional but may be a subject of further improvement/modification based on numerical experience with simulating seismic noise in a set of canonical structures and selected models of real sites in the course of work within the SESAME project.

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Introduction

Purpose: The program package NOISE is designed for computation of seismic noise in 3D heterogeneous surface geological structures with planar free surface due to surface and near-surface random sources.

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Availability and use of the program package:

Upon request from the authors.
The user is asked to make reference to the papers given below in case that he publishes results obtained with the program package since the program package NOISE is not published.

Moczo, P., J. Kristek, V. Vavrycuk, R.J. Archuleta, and L. Halada: 3D Staggered-grid Finite-difference Modeling with Volume Harmonic and Arithmetic Averaging of Elastic Moduli and Densities. Submitted to Bull. Seism. Soc. Am.

Kristek, J., P. Moczo and M. Kristekova: Finite-difference Simulation of Ambient Noise in 3D Surface. Sedimentary Structures: Part 1 - Method. In preparation.

Short description:

The program package consists of two programs written in Fortran95:
program RANSOURCE and program FDSIM.

Program RANSOURCE is designed for random space-time generation of point sources of seismic noise. The output files serve as input files for the program FDSIM. The algorithm of random noise generation assumes regular spatial distribution of potential point sources inside of a specified source volume. The spatial distribution is controlled by the prescribed minimum distance between two neighbour point sources, minimum distance between a point source and a receiver, and maximum distance between a point source and a receiver. The temporal distribution of point sources is controlled by the prescribed minimum and maximum numbers of point sources acting at the same time. For each generated position of a point source, a direction of acting single body force at the position, time function and maximum amplitude are randomly generated. The time function is either delta-like signal or pseudo-monochromatic signal (a harmonic carrier with the Gaussian envelope). Spectrum of the delta- like signal is low-pass filtered in order to fit the prescribed frequency range. In the case of the pseudo-monochromatic signal, first its duration, then its predominant frequency are randomly generated. The maximum amplitude of the signal is randomly generated from the interval (0,1> according to a chosen distribution. The program has to be run before the finite-difference simulation of the noise itself. The program generates two files for all delta-like sources and as many files as the number of generated pseudo-monochromatic sources. All the files serve as the input data files for the program FDSIM.

Program FDSIM is designed for the finite-difference simulation of seismic wave propagation and seismic ground motion in a 3D surface heterogeneous viscoelastic structure with a planar free surface. The computational algorithm is based on the explicit heterogeneous finite-difference scheme solving equations of motion in the heterogeneous viscoelastic medium with material discontinuities. The scheme is 4th-order accurate in space and 2nd-order accurate in time. The displacement-velocity-stress scheme is constructed on a staggered finite-difference grid. The computational region is represented by a volume of a parallelepiped with the top side representing a planar free surface, and bottom, rear, front, left and right sides representing either non-reflecting boundaries or planes of symmetry.
Different types of non-reflecting boundaries can be chosen on different sides of the computational region. The discontinuous spatial grid is used to cover the computational region. The upper part of the grid has three times smaller grid spacing than the lower part. Each part itself is a uniform rectangular grid. The rheology of the medium corresponds to the generalized Maxwell body. This makes it possible to account both for spatially varying quality factors of the P and S waves and for arbitrary Q-omega law. The wavefield is excited by a set of randomly generated point sources, each representing a single force acting in an arbitrary direction. The core memory optimization is applied in order to significantly reduce requirements of the computer’s core memory.

Acknowledgements:
The program package has been developed in the Geophysical Institute of Slovak Academy of Sciences, Bratislava, Slovak Republic, within the 5th Framework Program grant project EVG1-CT-2000-00026 "Site Effect Studies Using Ambient Excitations", SESAME.

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Program RANSOURCE

Program RANSOURCE is designed for random space-time generation of point sources of seismic noise. The output files serve as input files for the program FDSIM.

⇒ The flowchart of the program is presented in the file F_RANSOURCE.ps.

Algorithm

- point sources (PS) regularly distributed in a 'source volume';
  PSPSMIN - the minimum distance between two neighbouring point sources,
  PSRECMIN - the minimum distance between a point source and a receiver,
  PSRECMAX - the maximum distance between a point source and a receiver,

- miminum and maximum # of acting PS at the same time - MNS and MXS

Time function

- PDL % of PS have time function given by a filtered delta-like signal,
  (100-PDL) % of PS have time function given by a harmonic carrier with the Gaussian envelope;
- delta-like signal is given by a Gabor wavelet with the free-parameter values of fp=0.45, gama=0.1 and psi=0,
  ORDER is an order of a low-pass Butterworth frequency filter with a corner frequency FMAX applied to delta-like signal;
- frequency of a harmonic carrier is randomly picked up from the interval <FMIN, FMAX>, selected frequencies are uniformly distributed on a logarithmic scale (KEY_LOG_F = .TRUE.) or a linear scale (KEY_LOG_F = .FALSE.).

Amplitude

- maximum amplitude of each time function is randomly picked up from interval (0,1>, distribution of amplitude values in the interval (0,1> is given by an exponential function EF defined on the interval (0,1>. The minimum value of the function EF is EF(1) = DAMIN, the maximum value is EF(0) = DAMAX.

Source volume

Let H1 be some thickness in meters. H1 may represent a thickness of a flat surface layer, maximum depth of the sediment valley or other appropriate thickness.
Five different depth intervals define five different positions of a source volume in the vertical direction (variable SPLANE in the code):

```
SPLANE = 1 :  <    0,  H1/4>
SPLANE = 2 :  < H1/4, 3H1/4>
SPLANE = 3 :  <3H1/4, 5H1/4>
SPLANE = 4 :  <2H1  , 3H1  >
SPLANE = 5 :  <    0, 3H1  >
```

1. AUXILIARY FILE 'HFRANS'

JOBNAME (A17)

2. INPUT DATA FILE 'JOBNAME.IN'

```
NAMELIST /NAMES/        SR_FILE_NAME
```

SR_FILE_NAME= name of the output file containing parameters of the point sources (A20)

```
NAMELIST /CONTROLDATA/MT1,MT2, DT, MX, MY, LPAS, H,                &
                          MXS, FMIN, FMAX, KEY_LOG_F, SPLANE, H1,    &
                          DAMIN, DAMAX, PSPSMIN, PSRECMAX, PSRECMIN, &
                          ORDER, PDL
```

(REAL)

MT1, MT2 — The computations in FDSIM are performed from the time level MT1 until the time level MT2. (INTEGER)

DT — = time step in seconds. It has to satisfy the stability condition DT<=6/(7*SQRT(3))*R, where R is the minimum of the ratios (grid spacing)/(local P-wave velocity). (REAL)

MX, MY — Total numbers of the grid cells in the x- and y- directions (both horizontal) in the coarser grid. (The corresponding total numbers of the grid spacings are MX-1 and MY-1.) MX*MY is the total number of the grid cells in one horizontal grid plane. (INTEGER)

LPAS — The vertical grid index of the last grid plane of the finer grid and, at the same time, the first grid plane of the coarser grid. The first grid plane of the coarser grid shares the values of the z- components of the displacement and particle velocity, and the xz- and yz- stress-tensor components of the last grid plane of the finer grid. LPAS has to be larger than 4.
If LPAS == 0 then only coarser grid covers whole computational region.
(INTEGER)

H — Grid spacing in the coarser grid (in meters).
(The grid spacing in the finer grid is then H/3.)
(REAL)

MNS, MXS — (INTEGER)

FMIN, FMAX — (in Hz) (REAL)

KEY_LOG_F — (LOGICAL)

SPLANE — (INTEGER)

H1 — if LPAS > 0, H1 has to be smaller than (LPAS - 6)*H/3, (in meters)
(REAL)

DAMIN, DAMAX — (REAL)

PSPSMIN, PSRECMAX, PSRECMIN
if LPAS > 0, multiples of H/3
if LPAS = 0, multiples of H
(INTEGER)

ORDER, PDL — (INTEGER)

NAMELIST /REC/ MR

MR — = number of receivers (INTEGER)

IREC (J), KREC (J), LREC (J) ; J = 1, MR

IREC (J) — = grid index in the x- direction of the J-the receiver. All grid planes in the x- direction (i.e. the yz-planes) including those in the finer grid have to be considered if the receiver is located in the finer grid.
(INTEGER)

KREC (J) — = grid index in the y- direction of the J-th receiver. All grid planes in the y- direction (i.e. the xz-planes) including those in the finer grid have to be considered if the receiver is located in the finer grid.
(INTEGER)

LREC (J) — = grid index in the z- direction of the J-th receiver. All grid planes in the z- direction (i.e. the horizontal planes) including those in the finer grid have to be considered.
If LREC (J) == LPAS, the horizontal grid indices should only refer to the coarser grid.
(INTEGER)

3. OUTPUT DATA FILE SR_FILE_NAME

NAMELIST /SOURCE/ NPS

NPS — = number of point sources (INTEGER)

```
DO I = 1, NPS
  WRITE (10,*) IS(I), KS(I), LS(I), ITSB(I), ITSE(I)
  WRITE (10,*) CUS(I), CVS(I), CWS(I)
END DO
```

```
        IS (I)          = grid index in the x- direction of the I-th source. All grid
                          planes in the x- direction (i.e. the yz-planes) including
                          those in the finer grid have to be considered if the source is
                          located in the finer grid.
                                                                             (INTEGER)

        KS (I)          = grid index in the y- direction of the I-th source. All grid
                          planes in the y- direction (i.e. the xz-planes) including
                          those in the finer grid have to be considered if the source is
                          located in the finer grid.
                                                                             (INTEGER)

        LS (I)          = grid index in the z- direction of the I-th source. All grid
                          planes in the z- direction (i.e. the horizontal planes)
                          including those in the finer grid have to be considered. If LS
                          (I) == LPAS, the horizontal grid indices should only refer to
                          the coarser grid.
                                                                             (INTEGER)

       ITSB (I)         = time level corresponding to the initial time of the I-th
                          source's time function.
                                                                             (INTEGER)

       ITSE (I)         = time level corresponding to the end of the I-th source's
                          time function.
                                                                             (INTEGER)

        CUS (I)         = amplitude of the I-th source in the x- direction
        CVS (I)         = amplitude of the I-th source in the y- direction
        CWS (I)         = amplitude of the I-th source in the z- direction
                                                                            ALL (REAL)
```

4. OUTPUT DATA FILE(S) SRCxxxx.DAT

```
        SRCxxxx.DAT =  SRC0001.DAT, SRC0002.DAT,..., SRCvalu.DAT, where
                       val is the value of NPS
        SRCDELI.DAT
```

File SRC0001.DAT contains the source time function for the first source, SRC0002.dat for the second source, ...
File SRCDELI.DAT contains the source time function of the delta-like signal.
The files are direct-access files and are open in the code as follows:

```
      OPEN  ( 10, FILE = 'SRC0001.DAT', FORM ='UNFORMATTED',          &
              ACCESS = 'DIRECT',   RECL = PP,    STATUS='NEW' )
                       where
                       PP = 4 for single precision (default)
                          = 8 for double precision

 DO I = ITSB(1), ITSE(1)
   WRITE  ( 10, REC=I-ITSB(1)+1 ) SOURTF(I)
 END DO

      SOURTF(I)    = source time function at time level I
                                                         (REAL(PP))

   ==========================================================================
   ==========================================================================
```

Program FDSIM

Program FDSIM is designed for the finite-difference simulation of seismic wave propagation and seismic ground motion in a 3D surface heterogeneous viscoelastic structure with a planar free surface.

⇒ The flowchart of the program is presented in the file F_FDSIM.ps

1. AUXILIARY FILE 'HFFDSIM'

JOBNAME (A17)

2. INPUT DATA FILE 'JOBNAME.IN'

```
NAMELIST /NAMES/      MO_FILE_NAME,    Q_FILE_NAME,    &
                      JMH_FILE_NAME, JMH3_FILE_NAME,   &
                      SR_FILE_NAME
```

MO_FILE_NAME = name of the file containing elastic parameters and densities describing types of material cells (A20)

Q_FILE_NAME = name of the file containing anelastic parameters describing types of material cells (A20)

JMH_FILE_NAME = name of the file containing spatial distribution of material cell types in the coarser (i.e. lower) spatial grid whose grid spacing is H (A20)

JMH3_FILE_NAME = name of the file containing spatial distribution of material cell types in the finer (i.e. upper) spatial grid whose grid spacing is H/3 (A20)

SR_FILE_NAME = name of the file containing parameters of the point sources (A20)

```
NAMELIST /KEYS/      KEY_TLV, KEY_TLD, KEY_SNV, KEY_SND,  &
                     KEY_DISK
```

KEY_TLV = .TRUE.: Output file containing time levels of the particle velocities at specified receivers.
= .FALSE.: Output file is not generated. (LOGICAL)

KEY_TLD = .TRUE.: Output file containing time levels of the displacements at specified receivers.
= .FALSE.: Output file is not generated. (LOGICAL)

KEY_SNV = .TRUE.: Output file containing snapshots of the particle velocities at the free surface.
= .FALSE.: Output file is not generated. (LOGICAL)

KEY_SND = .TRUE.: Output file containing snapshots of the displacements at the free surface.
= .FALSE.: Output file is not generated. (LOGICAL)

KEY_DISK = .TRUE.: Field values are stored in disk memory.
= .FALSE.: Field values are stored in core memory. (LOGICAL)

```
NAMELIST /CONTROLDATA/  MT1  , MT2   , DT   , IPAS1 ,     &
                        MX   , MY    , MZ   , LPAS  , H , &
                        STRIP, IFILT, HWFILT
```

MT1, MT2 — The computations are performed from the time level MT1 until the time level MT2. If MT1 >2, the displacement and particle velocity values for the previous time levels have to be read in from the files. MT2 has to be equal to n*(STRIP-4)/3, where n is an integer number.
(INTEGER)

DT — = time step in seconds. It has to satisfy the stability condition DT<=6/(7*SQRT(3))*R, where R is the minimum of the ratios (grid spacing)/(local P-wave velocity).
(REAL)

IPAS1 — = 1: The displacement and/or particle velocity values at each time level are stored.
= 2 (3,...): The displacement and/or particle velocity values at each second (third,...) time level are stored.
(INTEGER)

MX, MY — Total numbers of the grid cells in the x- and y- directions (both horizontal) in the coarser grid. (The corresponding total numbers of the grid spacing are MX-1 and MY-1.) MX*MY is the total number of the grid cells in one horizontal grid plane.
(INTEGER)

MZ — Total number of the horizontal grid planes including all grid planes of the finer grid
(INTEGER)

LPAS — The vertical grid index of the last grid plane of the finer grid and, at the same time, the first grid plane of the coarser grid. The first grid plane of the coarser grid shares the values of the z- components of the displacement and particle velocity, and the xz- and yz- stress-tensor components of the last grid plane of the finer grid. LPAS has to be larger than 4 and smaller than MZ-2.
If LPAS == 0 then only coarser grid covers whole computational region.
(INTEGER)

H — Grid spacing in the coarser grid. (The grid spacing in the finer grid is then H/3.)
(REAL)

STRIP — Number of the horizontal grid planes in a moving subset of grid planes. STRIP has to be equal to 3*k + 4, where k is an integer number
(INTEGER)

IFILT — A symmetric FIR filter (specified in the input file FC.DAT) is applied to displacement and particle velocity fields at each IFILT-th time level.
If IFILT is not specified, no filtering is applied.
(INTEGER)

HWFILT — # of filter coefficients in FC.DAT
HWFILT has to be equal to k*(STRIP-4)/3-1, where k is an integer number.
(INTEGER)

```
     NAMELIST /ATTEN/     FRJMAX, FRANGE
```

ATTEN refers to inclusion of a realistic model of attenuation based on rheology of the Generalized Maxwell body.

FRJMAX = the maximum frequency [Hz] of the 8 relaxation frequencies in the model of the Generalized Maxwell body. FRJMAX should be equal to the maximum frequency up to which the computation should be sufficiently accurate, i.e. S/6, where S is the minimum of the ratios (local S-wave velocity)/(local grid spacing)
= 0: The attenuation is not included.
(REAL)

FRANGE determines the frequency range for the attenuation. FRANGE = 3, e.g., means frequency range < FRJMAX/10**3, FRJMAX >.
FRANGE should not be larger than 3. If it is, then accuracy of inclusion of the attenuation may be decreased.
(REAL)

```
  NAMELIST /NONREF/       OMG, WB,                                  &
                          KTLE,   KTRI,   KTRE,   KTFR,   KTBO,     &
                          THPPLE, THPPRI, THPPRE, THPPFR, THPPBO,   &
                          THSSLE, THSSRI, THSSRE, THSSFR, THSSBO
```

NONREF refers to nonreflecting boundaries of the grid. Several types of the nonreflecting boundaries are included.

OMG Dominant frequency [Hz] at which artificial reflections should be suppressed more than at other frequencies.
(REAL)

WB Weight coefficient for the Higdon boundary.
0.0 <= WB <= 0.4
(REAL)

KTLE Key determining type of the left-hand side boundary of the grid.
= 0: rigid boundary
= 1: Higdon
= 2: Reynolds
= 3: Peng & Toksoz, maximum attenuation set for the P waves for perpendicular displ. components
= 4: Emmerman & Stephen, max. attenuation set for the P waves for perpendicular displ. components
= 5: Clayton & Engquist A1
= 6: Peng Cheng Liu (original)
= 7: Peng Cheng Liu (maximum attenuation set for the P waves for perpendicular displ. components)
= 8: Peng Cheng Liu with a better approximation of the A1 conditions of Clayton & Engquist
= 9: Peng & Toksoz, maximum attenuation set for the S waves for all displ. components
(INTEGER)

KTRI Key determining type of the right-hand side boundary of the grid.
(INTEGER)

KTRE Key determining type of the rear boundary of the grid.
(INTEGER)

KTFR Key determining type of the front boundary of the grid.
(INTEGER)

KTBO Key determining type of the bottom boundary of the grid.
(INTEGER)

THPPLE — Angle theta [rad] for the P/P incidence/reflection at the left-hand side boundary for which the artificial reflection should be suppressed more than for other angles in the Peng & Toksoz boundary. (REAL)

THPPRI — The same as THPPLE but for the right-hand side boundary. (REAL)

THPPRE — The same as THPPLE but for the rear boundary. (REAL)

THPPFR — The same as THPPLE but for the front boundary. (REAL)

THPPBO — The same as THPPLE but for the bottom boundary. (REAL)

THSSLE — Angle theta [rad] for the S/S incidence/reflection at the left-hand side boundary for which the artificial reflection should be suppressed more than for other angles in the Peng & Toksoz boundary. (REAL)

THSSRI — The same as THSSLE but for the right-hand side boundary (REAL)

THSSRE — The same as THSSLE but for the rear boundary. (REAL)

THSSFR — The same as THSSLE but for the front boundary. (REAL)

THSSBO — The same as THSSLE but for the front boundary. (REAL)

NAMELIST /TXT — TEXT

TEXT — Arbitrary alphanumeric text (e.g. describing the computation). (A20)

NAMELIST /SNAP/ — IPAS2

Included only if KEY_SNV or KEY_SND == .TRUE.

IPAS2 — = 1: The displacement and/or particle velocity snapshots at each time level are stored.
= 2 (3,...): The displacement and/or particle velocity snapshots at each second (third,...) time level are stored. (INTEGER)

NAMELIST /REC/ — MR

MR — = number of receivers (INTEGER)

IREC (J), KREC (J), LREC (J) ; J = 1, MR

IREC (J) — = grid index in the x- direction of the J-th receiver. All grid planes in the x- direction (i.e. the yz-planes) including those in the finer grid have to be considered if the receiver is located in the finer grid. (INTEGER)

KREC (J) — = grid index in the y- direction of the J-th receiver. All grid planes in the y- direction (i.e. the xz-planes) including

those in the finer grid have to be considered if the receiver is located in the finer grid.
(INTEGER)

LREC (J) = grid index in the z- direction of the J-th receiver. All grid planes in the z- direction (i.e. the horizontal planes) including those in the finer grid have to be considered.
If LREC (J) == LPAS, the horizontal grid indices should only refer to the coarser grid.
(INTEGER)

3. INPUT DATA FILE SR_FILE_NAME

```
NAMELIST /SOURCE/      NPS
```

NPS = number of point sources
(INTEGER)

```
DO I = 1, NPS
  READ (10,*) IS(I), KS(I), LS(I), ITSB(I), ITSE(I)
  READ (10,*) CUS(I), CVS(I), CWS(I)
END DO
```

IS (I) = grid index in the x- direction of the I-th source. All grid planes in the x- direction (i.e. the yz-planes) including those in the finer grid have to be considered if the source is located in the finer grid.
(INTEGER)

KS (I) = grid index in the y- direction of the I-th source. All grid planes in the y- direction (i.e. the xz-planes) including those in the finer grid have to be considered if the source is located in the finer grid.
(INTEGER)

LS (I) = grid index in the z- direction of the I-th source. All grid planes in the z- direction (i.e. the horizontal planes) including those in the finer grid have to be considered.
If LS (I) == LPAS, the horizontal grid indices should only refer to the coarser grid.
(INTEGER)

ITSB (I) = time level corresponding to the initial time of the I-th source time function.
(INTEGER)

ITSE (I) = time level corresponding to the end of the I-th source time function.
(INTEGER)

CUS (I) = amplitude of the I-th source in the x- direction
CVS (I) = amplitude of the I-th source in the y- direction
CWS (I) = amplitude of the I-th source in the z- direction
ALL (REAL)

4. INPUT DATA FILE MO_FILE_NAME

```
READ ( 14 ) JMNUM
```

(INTEGER)

JMNUM = number of material cell types.

```
READ  ( 14 )            ( DENU(JM1), DENV(JM1), DENW(JM1),              &
                        LAM (JM1), MU  (JM1),                           &
                        MUXY(JM1), MUXZ(JM1), MUYZ(JM1), JM1 = 1, JMNUM)
```

DENU (I) = volume arithmetic average of the density [kg/m^3] in the grid position of the x- component of the displacement in the I-th type.
(REAL(PP))

DENV (I) = volume arithmetic average of the density [kg/m^3] in the grid position of the y- component of the displacement in the I-th type.
(REAL(PP))

DENW (I) = volume arithmetic average of the density [kg/m^3]in the grid position of the z- component of the displacement in the I-th type.
(REAL(PP))

MU (I) = Volume harmonic average of the torsion modulus in the grid position of the diagonal stress-tensor components in the I-th type. [Pa]
(REAL(PP))

LAM (I) = Lame's elastic coefficient 'lambda' in the grid position of the diagonal stress-tensor components in the I-th type. Value of this parameter is obtained as KAPA(I)-(2/3)MU(I), where KAPA is volume harmonic average of the bulk modulusin. [Pa]
(REAL(PP))

MUXY (I) = Volume harmonic average of the torsion modulus in the grid position of the xy- stress-tensor component in the I-th type. [Pa]
(REAL(PP))

MUXZ (I) = Volume harmonic average of the torsion modulus in the grid position of the xz- stress-tensor component in the I-th type.. [Pa]
(REAL(PP))

MUYZ (I = Volume harmonic average of the torsion modulus in the grid position of the yz- stress-tensor component in the I-th type. [Pa]
(REAL(PP))

PP = 4 for single precision (default)
= 8 for double precision

5. INPUT DATA FILE Q_FILE_NAME

```
READ  ( 15 ) ( YLAM (JM1,1:8), YMU  (JM1,1:8),                       &
               YMUXY(JM1,1:8), YMUXZ(JM1,1:8), YMUYZ(JM1,1:8),       &
                                                  JM1 = 1, JMNUM)
```

YLAM (I,IFREQ) = value of the anelastic material parameter at the IFREQ-th relaxation frequency corresponding to YKAPA(I)*KAPA(I)-(2/3)YMU(I)*MU(I).
(REAL(PP))

YMU (I,IFREQ) = value of the anelastic material parameter at the IFREQ-th relaxation frequency corresponding to MU(I).
(REAL(PP))

YMUXY(I,IFREQ) = value of the anelastic material parameter at the IFREQ-th relaxation frequency corresponding to MUXY (I).
(REAL(PP))

YMUXZ(I,IFREQ) = value of the anelastic material parameter at the IFREQ-th relaxation frequency corresponding to MUXZ (I).
(REAL(PP))

```
YMUYZ(I,IFREQ)     = value of the anelastic material parameter at the IFREQ-th
                     relaxation frequency corresponding to MUYZ (I).
                                                                     (REAL(PP))

                       PP = 4 for single precision (default)
                          = 8 for double precision
```

6. INPUT DATA FILE JMH_FILE_NAME

The file is a direct-access file and is open in the code as follows:

```
INQUIRE ( IOLENGTH = IOLENINT )   JM (1:MX,1:MY,1:1)

OPEN ( 13, FILE   = JMH_FILE_NAME, FORM = 'UNFORMATTED',             &
           ACCESS = 'DIRECT',   RECL = IOLENINT,      STATUS='OLD' )


DO L = LPAS, MZ
  READ  (13, REC = L+1-LPAS)  JM( 1:MX,1:MY, L)
END DO
```

```
JM (I,K,L)        = integer number specifying a type of block in the (I,K,L)-th
                    grid cell.
                                                                  (INTEGER*2)
```

7. INPUT DATA FILE JMH3_FILE_NAME

The file is a direct-access file and is open only if LPAS>0 in the code as follows:

```
INQUIRE ( IOLENGTH = IOLENINT )   JMF (1:MXF,1:MYF,1:1)
                     where
                     MXF = (MX-1)*3 + 1, MYF = (MY-1)*3 + 1

OPEN ( 33, FILE   = JMH3_FILE_NAME, FORM = 'UNFORMATTED',            &
           ACCESS = 'DIRECT',   RECL = IOLENINT,      STATUS='OLD' )


DO L = 0, LPAS
  READ  (33, REC = L+1)  JMF( 1:MXF,1:MYF, L)
END DO
```

```
JMF (I,K,L)       = integer number specifying a type of block in the (I,K,L)-th
                    grid cell.
                                                                  (INTEGER*2)
```

8. INPUT DATA FILE(S) SRCxxxx.DAT - generated by the RANSOURCE program

```
SRCxxxx.DAT =  SRC0001.DAT, SRC0002.DAT,..., SRCvalu.DAT, where
               val is the value of NPS
SRCDELI.DAT
```

File SRC0001.DAT contains the source time function for the first source, SRC0002.dat for the second source, ...
The files are directly-access files and are open in the code as follows:

```
OPEN  ( 10, FILE = 'SRC0001.DAT', FORM ='UNFORMATTED',          &
        ACCESS = 'DIRECT',   RECL = PP,    STATUS='OLD' )
                 where
                 PP = 4 for single precision (default)
                    = 8 for double precision

DO I = ITSB(1), ITSE(1)
  READ  ( 10, REC=I-ITSB(1)+1 ) SOURTF(I)
END DO
```

```
      SOURTF(I)    = source time function at time level I
                                                          (REAL(PP))
```

9. INPUT DATA FILE FC.DAT

```
   Each line of the file contains a value of one filter coefficient.
   1st line : Zero-th coefficient,
   2nd line : 1st coefficient,
   ...
   HWFILT + 1 line: HWFILT-th coefficient


OUTPUT FILES:
=============

If  KEY_TLD == .TRUE.

    SEISU.DAT  - ascii file containing values of the x-component of displacement
                 at specified receivers at each IPAS1 time level, e.g.
                1st column - time
                2nd column - displacement values at receiver 1
                3rd column - displacement values at receiver 2
                                        .
                                        .
                                        .
                (MR+1)th column - displacement values at receiver MR

    SEISV.DAT  - the same as SEISU.DAT but for y-component
    SEISW.DAT  - the same as SEISU.DAT but for z-component

                NOTE! The order of receiver has to be read from JOBNAME.LOG file!

    SEISU0.DAT - the x-component of displacement interpolated at the grid position
                 of the z-component at the free surface
    SEISV0.DAT - the same as SEISU0.DAT but for the y-component
    SEISW0.DAT - the same as SEISW.DAT
               -
If  KEY_TLV == .TRUE.

    VELOU.DAT  - ascii file containing values of the x-component of particle
                 velocity at specified receivers at each IPAS1 time level, e.g.
                1st column - time
                2nd column - particle velocity values at receiver 1
                3rd column - particle velocity values at receiver 2
                                        .
                                        .
                                        .
                (MR+1)th column - particle velocity values at receiver MR

    VELOV.DAT  - the same as VELOU.DAT but for y-component of particle velocity
    VELOW.DAT  - the same as VELOU.DAT but for z-component of particle velocity

                NOTE! The order of receiver has to be read from JOBNAME.LOG file!

    VELOU0.DAT - the x-component of partcile velocity interpolated
                 at the grid position of the z-component at the free surface
    VELOV0.DAT - the same as VELOU0.DAT but for the y-component
    VELOW0.DAT - the same as VELOW.DAT

If  KEY_SND == .TRUE.

  If  KEY_WC == .FALSE.
    SNAP.Dxxxxx - unformatted file containing displacement values at the
                  free surface at time level xxxxx (,e.g. SNAP.D00010, for
                  10-th time level)
      WRITE ( 18 ) UFM(1:MXF,1:MYF,1),                                 &
                   VFM(1:MXF,1:MYF,1),                                 &
```

```
                 WFM(1:MXF,1:MYF,1)
  else
    SNAP.Dxxxxx - unformatted file containing wavelet compressed
                  displacement values at the free surface
                  at time level xxxxx (,e.g. SNAP.D00010, for
                  10-th time level)


If  KEY_SNV == .TRUE.

  If  KEY_WC == .FALSE.
    SNAP.Vxxxxx - unformatted file containing particle velocity values at the
                  free surface at time level xxxxx (,e.g. SNAP.V00010, for
                  10-th time level)
      WRITE ( 18 ) UF (1:MXF,1:MYF,1),                                 &
                   VF (1:MXF,1:MYF,1),                                 &
                   WF (1:MXF,1:MYF,1)
  else
    SNAP.Vxxxxx - unformatted file containing wavelet compressed
                  particle velocity values at the free surface
                  at time level xxxxx (,e.g. SNAP.D00010, for
                  10-th time level)


Note about stop and continue computations:
==========================================
If it is necessary to stop the computation before reaching MT2 time level:
   -  create an empty file with name 'STOP' in the directory where the computation is
      running
   -  if it will be desirable to continue the computation after stopping and KYE_DISK
      was set to .FALSE. then create an empty file with name 'DISK' in th directory
      where computation is running.
   -  after while the computation will be stopped and in the file 'STOP' it will be
      written number of the following first time level

to continue the computation:
   -  delete the temporary files JOBNAME.BOU, JOBNAME.BOF, JOBNAME.REC, JOBNAME.SRC
   -  KEEP the files WAVE.CF* and WAVE.CO*, SEIS.TL*, VELO.TL*
   -  set MT1 equal to the number stored in the file 'STOP'
   -  run the computation
```


Acknowledgements

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List of Appendices

Appendix 1: Canonical models

Appendix 2: CD ROM with the program NOISE

Appendix 1 : Canonical models

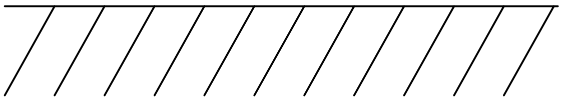
A set of canonical models for seismic noise simulations has been defined. The set of the canonical models will serve for extensive parametric study of synthetic seismic noise which will create a basis for deducing systematic features of the noise and decisive factors determining peak H/V and HT (VT) frequencies and corresponding amplitudes.

The set consists of the following models (each being described in the following pages):

- M1 : homogeneous halfspace,
- M2 : single layer over halfspace
  - parameter study with several mechanical parameters
  - single layer over halfspace – Grenoble,
  - single layer over halfspace – Liege,
- M3 : dipping layer, semiinfinite layer over halfspace,
- M4 : semi-infinite layer over halfspace,
- M5 : single layer with a rough layer-halfspace interface,
- M6 : deep sediment valley
  - A – 2D case
  - B – 3D, axisimmetric case
- M7 : shallow sediment valley
  - A – 2D case
  - B – 3D, axisimmetric case
- M8 : single layer with a trough at the bottom
  - A – 2D case
  - B – 3D, axisimmetric case
- M9 : buried fault
- M10 : two-layer models
  - A – thick and shallow layers
  - B – two shallow layers, with and without velocity inversion
- M11 : shallow layer, gradient model
  - A – with increasing velocity
  - B – with decreasing velocity

The set of the canonical models will serve for extensive parametric study of synthetic seismic noise which will create a basis for deducing systematic features of the noise and decisive factors determining peak H/V and HT (VT) frequencies and corresponding amplitudes.

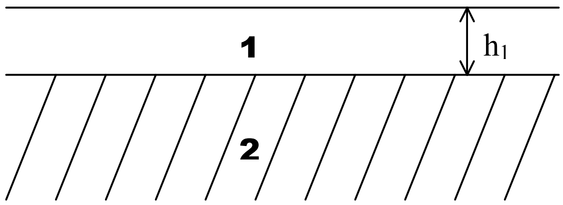
• M1: Homogenous halfspace



α = 2000 m/s	β = 1000 m/s	ρ = 2500 kg/m^3	Q_S = 50 Q_P = 100

• M2: Single layer over halfspace

➢ Parameter study with several mechanical parameters



α_1 (m/s)	β_1 (m/s)	h_1 (m)	
400 – 1350	200	25	ρ_1 = 1900 kg/m^3
500 – 1350	250	31.25	Q_{S1} = 25
667 – 1350	333	41.6	Q_{P1} = 50
1000 – 1350	500	62.5	f_0 = 2 Hz
1350	667	83	f_{max} = 10 Hz
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 kg/m^3	Q_{S2} = 50 Q_{P2} = 100

α_1/β_1 \ β_2/β_1	1.5	2.0	3.0	4.0	5.0
2	YES	YES	YES	YES	YES
3		MAYBE	MAYBE	MAYBE	MAYBE
4			YES	YES	YES
5				MAYBE	MAYBE
10					YES

➢ Single layer over halfspace - Grenoble

Thickness of the layer: h_1 = 500 m

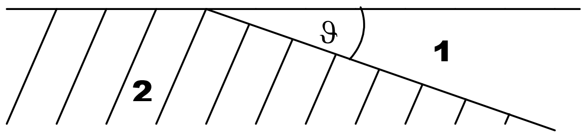
α_1 = 1800 m/s	β_1 = 600 m/s	ρ_1 = 2000 kg/m^3
α_2 = 5000 m/s	β_2 = 3000 m/s	ρ_2 = 2500 kg/m^3

➢ Single layer over halfspace - Liège

Thickness of the layer: h_1 = 10 m

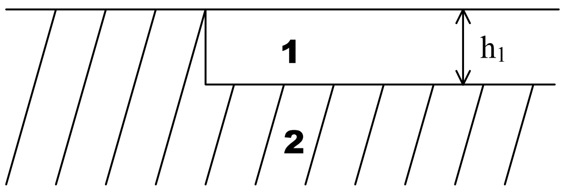
α_1 = 1350 m/s	β_1 = 200 m/s	ρ_1 = 1900 kg/m^3
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 kg/m^3

- **M3: Dipping layer**



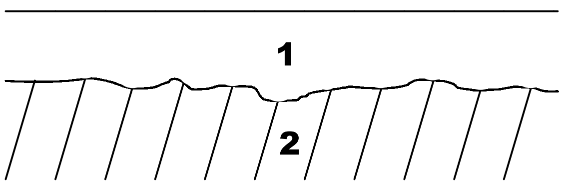
α_1 = 1350 m/s	β_1 = 250 m/s β_1 = 500 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50	ϑ
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100	10° 20°

- **M4: Semiinfinite layer over halfspace**



α_1 = 1350 m/s	β_1 = 250 m/s β_1 = 500 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50	h_1 (m)
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100	31,25 62,5

- **M5: Single layer with a rough layer halfspace interface**



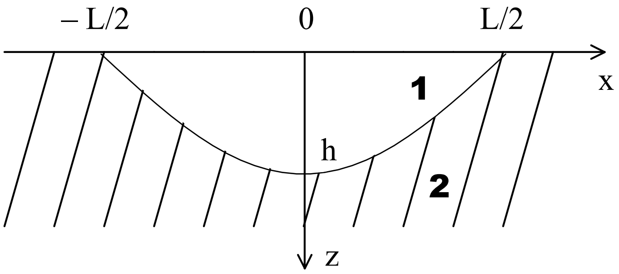
α_1 = 1350 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

Average thickness of the layer: $\overline{h}$ = 31,25 m

Amplitude of the roughness: 15 % of the layer thickness
30 % of the layer thickness

Correlation length: $\frac{1}{2}\frac{\beta_1}{f_0}$, $\frac{\beta_1}{f_0}$, $2\frac{\beta_1}{f_0}$

- **M6: Deep sediment valley**



➤ **A – 2D case**

Interface between sediments and bedrock is defined by

$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

$$z = 0 \quad , \quad x \notin \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

Width of the valley: L = 2500 m
Depth of the valley: h = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

➤ **B – 3D, axisimmetric case**

Interface between sediments and bedrock in the xz-plane is defined by

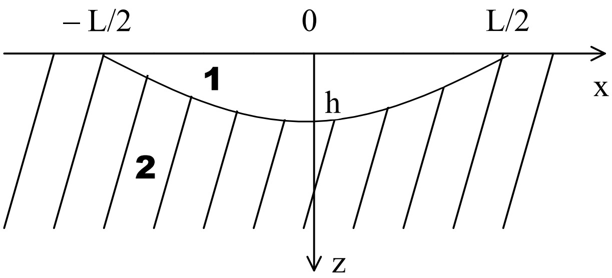
$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

$$z = 0 \quad , \quad x \notin \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

Width of the valley: L = 2500 m
Depth of the valley: h = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

- **M7: Shallow sediment valley**



➢ **A – 2D case**

Interface between sediments and bedrock is defined by

$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

$$z = 0 \quad , \quad x \notin \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

1st model: L_1 = 5000 m
h_1 = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

2nd model: L_2 = 312,5 m
h_2 = 31,25 m

α_1 = 1350 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

➢ **B – 3D, axisimmetric case**

Interface between sediments and bedrock in the xz-plane is defined by

$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

$$z = 0 \quad , \quad x \notin \left\langle -\frac{L}{2}, \frac{L}{2} \right\rangle$$

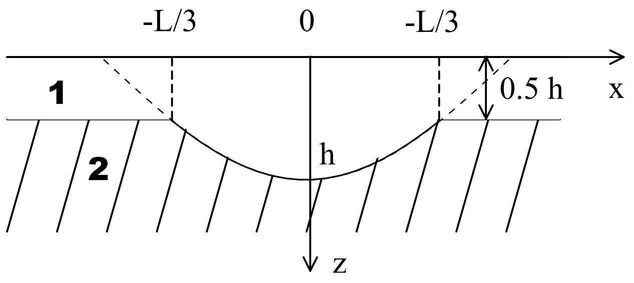
1st model: L_1 = 5000 m
h_1 = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

2nd model: L_2 = 312,5 m
h_2 = 31,25 m

α_1 = 1350 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

• M8: Single layer with a through at the bottom



➢ A – 2D case

Interface between sediments and bedrock is defined by

$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{3}, \frac{L}{3} \right\rangle$$

$$z = \frac{h}{2} \quad , \quad x \notin \left\langle -\frac{L}{3}, \frac{L}{3} \right\rangle$$

1st model: L_1 = 2500 m
h_1 = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

2nd model: L_2 = 312,5 m
h_2 = 31,25 m

α_1 = 1350 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

➢ B – 3D, axisimmetric case

Interface between sediments and bedrock in the xz-plane is defined by

$$z = h.\cos\left(\frac{\pi}{L}x\right) \quad , \quad x \in \left\langle -\frac{L}{3}, \frac{L}{3} \right\rangle$$

$$z = \frac{h}{2} \quad , \quad x \notin \left\langle -\frac{L}{3}, \frac{L}{3} \right\rangle$$

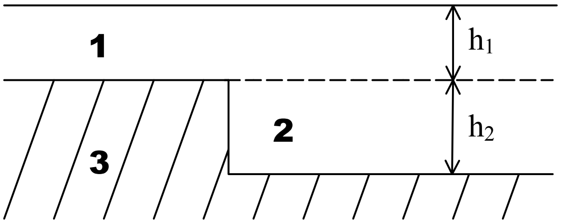
1st model: L_1 = 2500 m
h_1 = 500 m

α_1 = 1800 m/s	β_1 = 667 m/s	ρ_1 = 2000 m/s	Q_{S1} = 50 Q_{P1} = 100
α_2 = 3500 m/s	β_2 = 2000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 100 Q_{P2} = 200

2nd model: L_2 = 312,5 m
h_2 = 31,25 m

α_1 = 1350 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

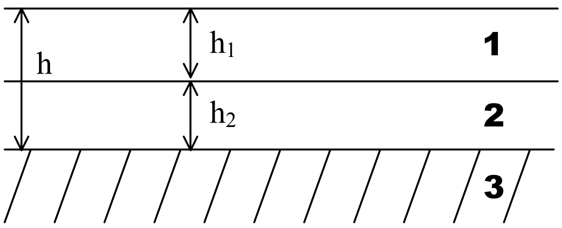
- **M9: Burried fault**



h_1 = 31,25 m
h_2 = 375 m

α_1 = 500 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 1800 m/s	β_2 = 750 m/s	ρ_2 = 2100 m/s	Q_{S2} = 50 Q_{P2} = 100
α_3 = 3900 m/s	β_3 = 2250 m/s	ρ_3 = 2500 m/s	Q_{S3} = 100 Q_{P3} = 200

- **M10: Two layer models**



- **A – thick and shallow layers**

h_1 = 31,25 m
h_2 = 375 m

α_1 = 500 m/s	β_1 = 250 m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 1800 m/s	β_2 = 750 m/s	ρ_2 = 2100 m/s	Q_{S2} = 50 Q_{P2} = 100
α_3 = 3900 m/s	β_3 = 2250 m/s	ρ_3 = 2500 m/s	Q_{S3} = 100 Q_{P3} = 200

- **B – thick and shallow layers, with and without velocity inversion**

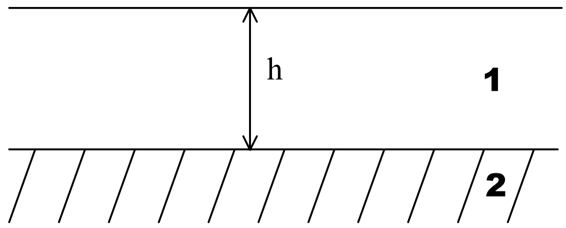
1st model: h_1 = 18 m
h_2 = 18 m

α_1 = 1350 m/s	**β_1 = 250 m/s**	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 1350 m/s	**β_2 = 333 m/s**	ρ_2 = 1900 m/s	Q_{S2} = 25 Q_{P2} = 50
α_3 = 2000 m/s	β_3 = 1000 m/s	ρ_3 = 2500 m/s	Q_{S3} = 50 Q_{P3} = 100

2nd model: h_1 = 18 m
h_2 = 18 m

α_1 = 1350 m/s	**β_1 = 333 m/s**	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 1350 m/s	**β_2 = 250 m/s**	ρ_2 = 1900 m/s	Q_{S2} = 25 Q_{P2} = 50
α_3 = 2000 m/s	β_3 = 1000 m/s	ρ_3 = 2500 m/s	Q_{S3} = 50 Q_{P3} = 100

- **M11: Shallow layer, gradient model**



- **A – with increasing velocity**

h = 36 m

α_1 = 1350 m/s	β_1 = 200 + 5z m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

- **B – with decreasing velocity**

h = 36 m

α_1 = 1350 m/s	β_1 = 380 – 5z m/s	ρ_1 = 1900 m/s	Q_{S1} = 25 Q_{P1} = 50
α_2 = 2000 m/s	β_2 = 1000 m/s	ρ_2 = 2500 m/s	Q_{S2} = 50 Q_{P2} = 100

Appendix 2: Program NOISE

see the CD ROM attached to this report.