Synthetic Seismogram Calculation using the Reflectivity Method.

Purpose of the code: Compute complete synthetic seismograms based on the following required elements:

   (1) A 1-D layered earth model containing Vp, Vs, density, Qa, Qb (Qs are quality factors of the material related to P and S speeds, inverse of attenuation) of each layer.
   (2) A range of slownesses (related to a range of ray parameters, meaning a range of different ray types) that will be considered in the computation. For example, to have S and P both on your output program, you need to make sure that the slowness range is big enough to contain 1/9=0.11 and 1/5=0.2. Just an example.
   (3) A range of frequencies for waves to compute. So far we have worked primarily with one
   ω, but there are many frequencies to consider. Some are more prominent than others for a particular ray parameter (phase).
   (4) Nyquist frequency and the number of frequencies. The number of frequencies to compute also dictates the time samples (num_of_frequency x 2). The maximum frequency is usually set to be the highest frequency.
   (5) Source depth, station depth
   (6) Epicentral distance between source and station.
   (7) Depends on the specific code, some codes (such as the one we are using) takes source into consideration. It uses the so called Moment tensor elements (force couple representation of radiation pattern) as input. If source is required, we also need to give the azimuth of the station from source since it dictates the how the unique path is affected by the source radiation pattern (whether the path goes through a compressive or dilatation regime).

Specific Instructions for "myreflecvity":

This specific version of Reflectivity Method: Originally written by Bob Hermann and coauthors, edited by a variety of people, myself included to suit my research purposes.

Input file structure: modeltest.in

Line 1:   6 (total number of layers in the model)
Line 2:   1.0 5.00 2.910 2.50 300 150
   The above columns are
   Layer_thickness (in km)   Vp (in km/s), Vs (km/s), density (kg/m^3), Qa and Qb
Line 7: 0.00 8.15 ...
   This is the last layer with 0 thickness. Below which there is no more model. That means if the maximum depth of the ray exceed this layer, that particular type of ray will not be computed since it will not "come back to surface"
Line 8: 0.0001 0.05   0.38   0.4   0.0002
   0.0001: Minimum slowness s. So 1/s gives fastest allowed seismic wave speed. You need to make sure your wave of interest is below that.

0.05 :   A lower-corner of a slowness range shaped like a trapezoid. Between 1.0E-4 and 0.05, the slowness filter falls off quickly. Using corners avoids ringing.

0.38:   High pass slowness corner.

0.40:   Maximum slowness. Or the slowest wave speed allowed which is 2.5 km/s.

0.0002:   slowness increment within that range (this dictates how many slownesses we would like to integrate over).

Line 9:   0.0   0.5   0.5   512

0.0 ---- minimum frequency in Hz. This means that our frequency range is all
     inclusive down to very long period waves.

0.5 --- maximum frequency. This says that the minimum period of the wave is
1/0.5=2 seconds. So anything higher than, say1 Hz signals are not computed.

0.5 --- Nyquist frequency. Note it is usually set to be the same as the maximum
frequency. You can't have a max frequency higher than the Nyquist. The Nyquist
frequency also dictates the sampling rate. By having 0.25 Hz Nyquist, we have a
period T of 4 sec, that means the sampling rate must be half which means the
sampling rate is 2 sec.

512 --- Number of time points.   This also means that the actual number of
frequencies = 256. You have to make sure this range will contain the seismic arrival
that you are interested in, say S wave, or SS, etc.

Line 10:   1   (1 earthquake only)

Line 11:   3   (3 stations that I wish to compute)

Line 12-14 (distance in **kilometers   azimuth**)

   400   200   (this means 400 km distance,   azimuth is 200 degrees)

   Note: it is not station back-azimuth but source azimuth which points from source
to station.

Line 15: 5.0   (earthquake source depth in kilometers)

Line 16 – 18: 0.1   Station depth in kilometers for the 5 respective stations. You should
put something close to 0 in general since you will be using ground stations (this file was
used for ocean bottom seismometers).

Line 19:   source Moment Tensor Elements.
Check www.seismology .Harvard.edu (CMT projects) to search for an earthquake and
find the associated "beachballs". These beachballs are generated by a tensor (also 3x3
symmetric like the stress tensors) that describes the forces at the source. The Harvard
CMT solutions in POLAR coordinates which you need to change to Cartesian
coordinates. See **Aki and Richards** (*Quantitative Seismology*) for conventions. A
program to convert it back and forth is called   **conv_momten (the output format is the
one you need to put into the program, not the global CMT one!)**

Line 20: 2 (an option in the inversion using this code --- yes, this code allows an inversion) that links the P and S speeds, or links P, S and density together in some way. Keep it at 2 for now).

Running procedures:

1. To run the code and generates an synthetic seismogram for a few simple faulting type:
   myreflectivity
   the program asks you input file, enter   **modeltest.in**
   then program asks you output file, enter   **your_output_name**
2. The program runs and the output file is actual binary. To convert from the basic fault synthetics to VERTICAL, RADIAL and TRANSVERSE seismograms, you need to run another program called   "**mysynd_new**":
   >> **mysynd_new**
   enter the Green function file:
     your_output_name
   enter the exponent of scalar moment in dyne-cm (integer):
               say   27   (this really depends on your source, the number can be obtained from the Harvard CMT mechanism report)
   Output options: 1—3
     Choose 2
   Output station number:
     Say 1 (this will output 3 component seismograms for station 1)
   Enter output file:
     Your_desired_name

   3,   You are ready to view your synthetic seismogram. The output synthetic seismograms are in ASCII format with 2 columns (take a look). The first column is the time (doesn't necessarily start at 0 sec) and the second is the wave amplitude in meters. You can use matlab to read them or use a cool program called xmgr (very user friendly), type
        xmgrace Your_desired_name.*
   This will view all 3 components called Your_desired_name.V
   Your_desired_name.R and Your_desired_name.T

   If xmgrace does not work, use Matlab.

   The output seismogram has not been filtered. It is sampled at 2 sec per sample for 256 time points, resulting in a total duration of 512 seconds.   If you see significant energy starting at 0 time, that means your time window is too short (like in this case) such there are significant wrap-around effect resulting from a big seismic phase arriving at the end of the time window.

Filtering a seismogram: Must be evenly sampled also in ASCII FORMAT

➢ **applyfilter**
  Your_seismogram_file
  Your_desired_output.filtered
  0.02 0.1

This is a small program I wrote in Fortran that applies the buttersworth filter (should not sound strange to most of you, maybe just Heather). The third input "0.02 0.1" filters between 0.02 Hz and 0.1 Hz, that means a period range of 10 sec and 50 sec. Frequencies higher or lower than this range will be attenuated. Check different filter parameters and see the differences.