Geo-Physical Imaging Homework

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1 Introduction

This report documents a series of simulations using a 2-D finite-difference acoustic simulator to model wave propagation in various types of mediums. The simulations focus on different acquisition geometries, the measurement of seismic energy decay as a function of distance from the source and more.

2 Prerequisites

Prior to starting the simulations it is important to understand the simulation tool and methods used. The simulations were performed on Matlab using the acoustic wave equation finite difference simulator. The simulator's input parameters are listed below,

- Velocity model
- Source parameters
- Simulator parameters
- Receiver positions *(Optional)*

On providing the above parameters to the simulator as input it produces the following output,

- Evolving acoustic pressure field amplitude
- Seismic Trace at the reciever

2.1 Model Parameters

The model parameters that are necessary for the simulation are listed below,

- $model.x$: vector of x grid co-ordinates $[m]$, Nx elements
- $model.y$: vector of y grid co-ordinates $[m]$, Ny elements
- $model.vel$: vector of velocity values $[m/s]$, (Nx, Ny) elements

The optional model parameters are,

- $model.recx$: vector of x co-ordinates of the receivers $[m]$, Nr elements
- $model.recz$: vector of z co-ordinates of the receivers $[m]$, Nr elements
- $model.dtrec$: max time sampling interval for seismic trace $[s]$

2.2 Source Parameters

The source parameters that are necessary for the simulation are listed below,

- $source.x$: x co-ordinate of the source $[m]$
- $source.z$: z co-ordinate of the source $[m]$
- $source.f0$: central frequency f_0 of source Ricker wavelet $[Hz]$
- $source.type$: 1 is Ricker wavelet, 2 is sinusoid at frequency f_0 $[Hz]$
- $source.amp$: multiplier of the source amplitude

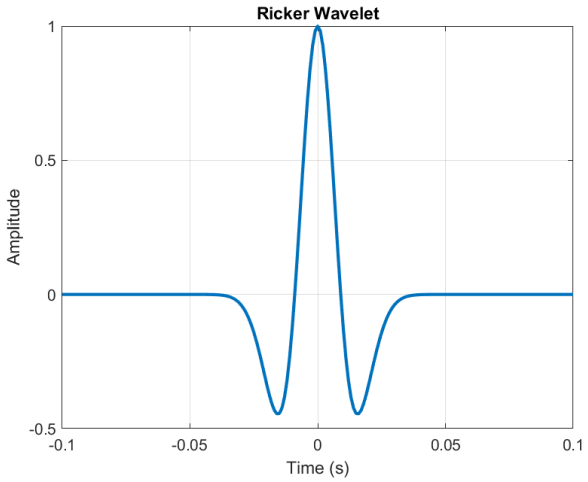


Figure 1: Ricker wavelet visualized.

2.3 Simulation

Initiation of the simulation is achieved by performing a program call of the *acu2Dpro* method. The method takes the model, source, and simulation parameters as its input arguments. *acu2Dpro* outputs the recorded data. The recorded data contains the following,

- $recfield.time$: time axis of recorded signal $[s]$, Nt elements
- $recfield.data$: matrix of pressure at the receivers, (Nt, Nr)
- $recfield.recx$: vector of x grid coordinates of receiver $[m]$, Nr elements
- $recfield.recz$: vector of z grid coordinates of receiver $[m]$, Nr elements

3 Theory

The excitation signal at the source used in the simulation can be of two kinds, namely, Ricker wavelet, as shown in figure 1 and sinusoidal signal.

The Ricker wavelet $f(t)$ is expressed as:

$$f(t) = (1 - 2\pi^2 f_0^2 t^2) e^{-\pi^2 f_0^2 t^2} \tag{1}$$

where:

- f_0 is the peak frequency (Hz).
- t is the time (s).

4 Simulation Results

4.1 Exercise B1

The results obtained after executing the example simulations are shown in figures. 2, 3, 4, 5, 6, 7, and 8.

The simulations in these examples details the different concepts encountered during seismic activities, such as, reflection, refraction, guide waves, effect of different velocities, a realistic model, and much more.

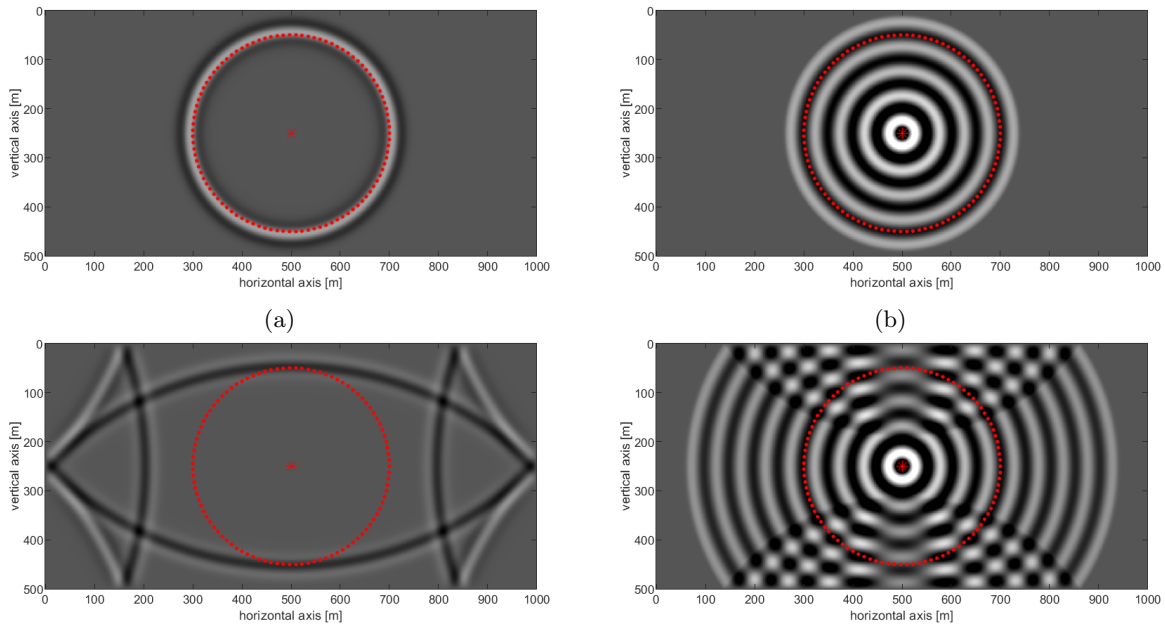


Figure 2: Example 1: Evolving traces with (a) Ricker wavelet with absorbing borders, (b) Sinusoidal wave with absorbing borders, (c) Ricker wavelet with non absorbing borders, and (d) Sinusoidal wave with non absorbing borders.

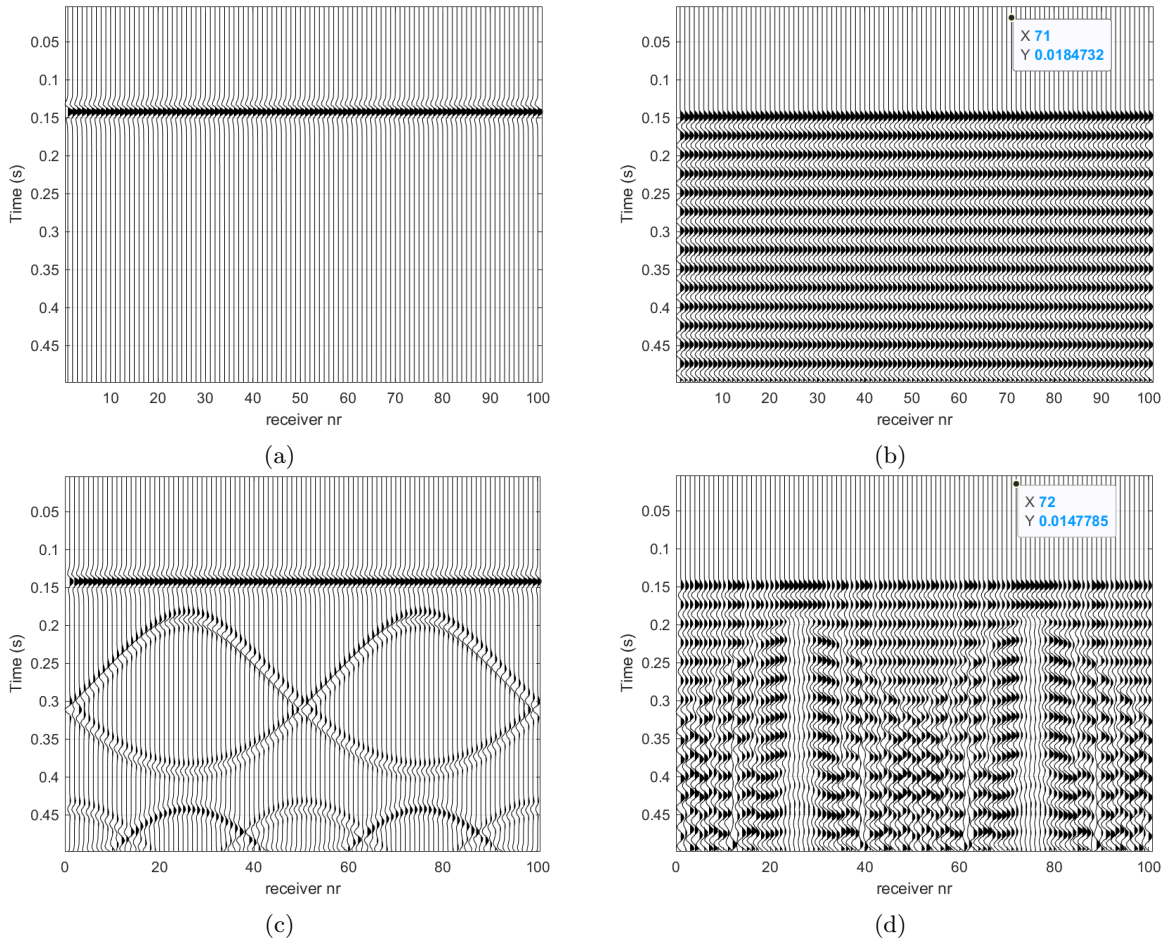


Figure 3: Example 1: Seismic trace of (a) Ricker wavelet with absorbing borders, (b) Sinusoidal wave with absorbing borders, (c) Ricker wavelet with non absorbing borders, and (d) Sinusoidal wave with non absorbing borders.

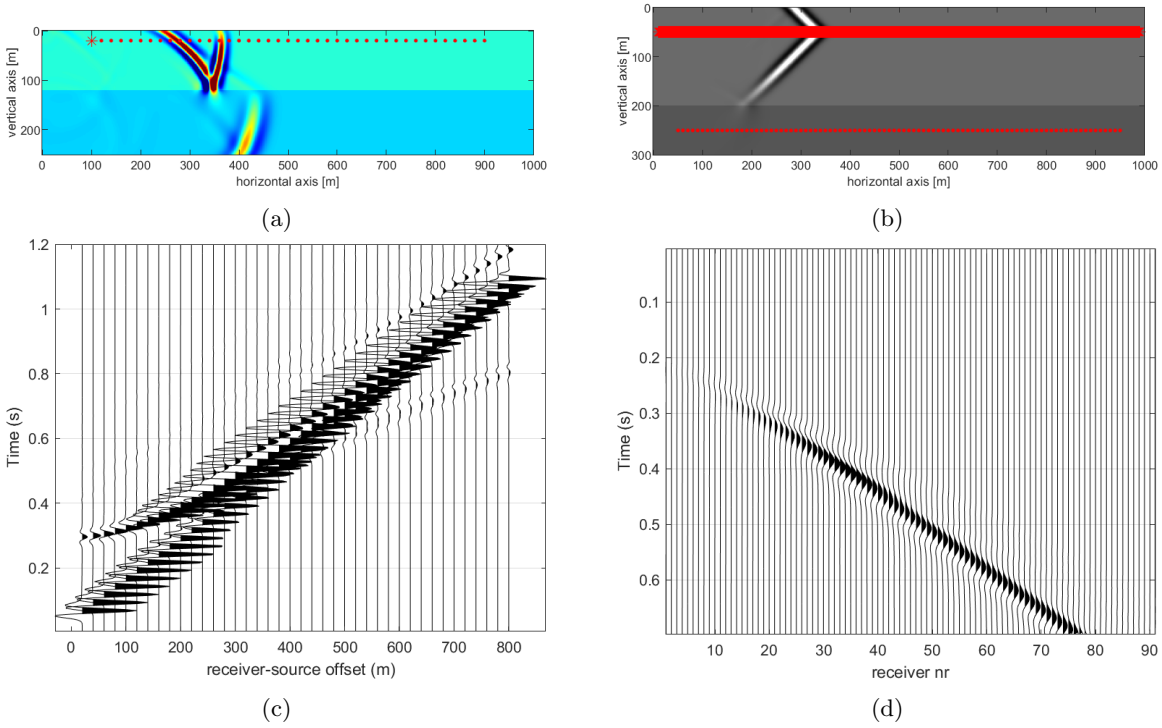


Figure 4: Example 2 & 3: Evolving traces with (a) Ricker wavelet with two mediums of differing wave velocity, (b) line of point sources with two mediums of differing wave velocity, (c) Seismic trace for scenario (a), (d) Seismic trace for scenario (b).

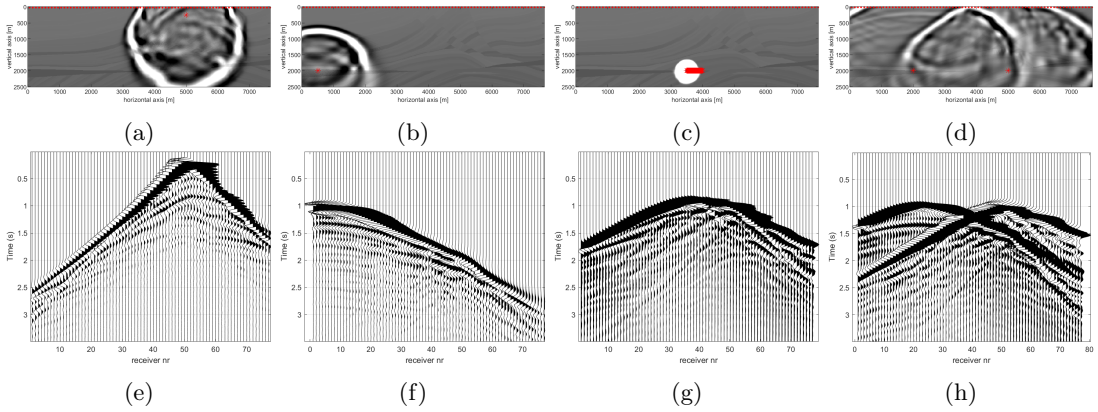


Figure 5: Example 4: Evolving traces with (a)-(d) Ricker wavelet on a realistic model with varying source positions and amplitudes, (e)-(h) Seismic trace for scenario (a)-(d), respectively.

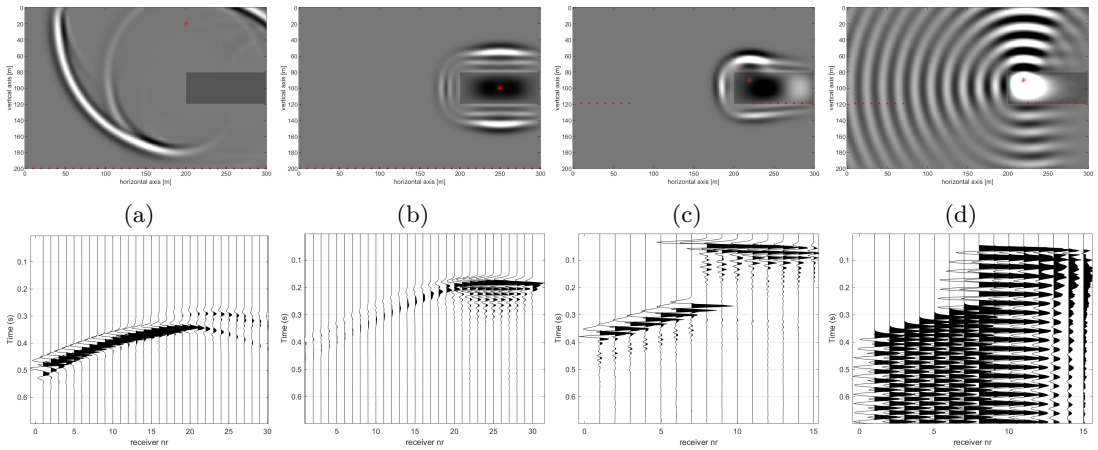


Figure 6: Example 5: Visualization of Huygen's principle using evolving traces with (a)-(d) Ricker wavelet with source and receivers placed at different positions on the model, (e)-(h) Seismic trace for scenario (a) - (d).

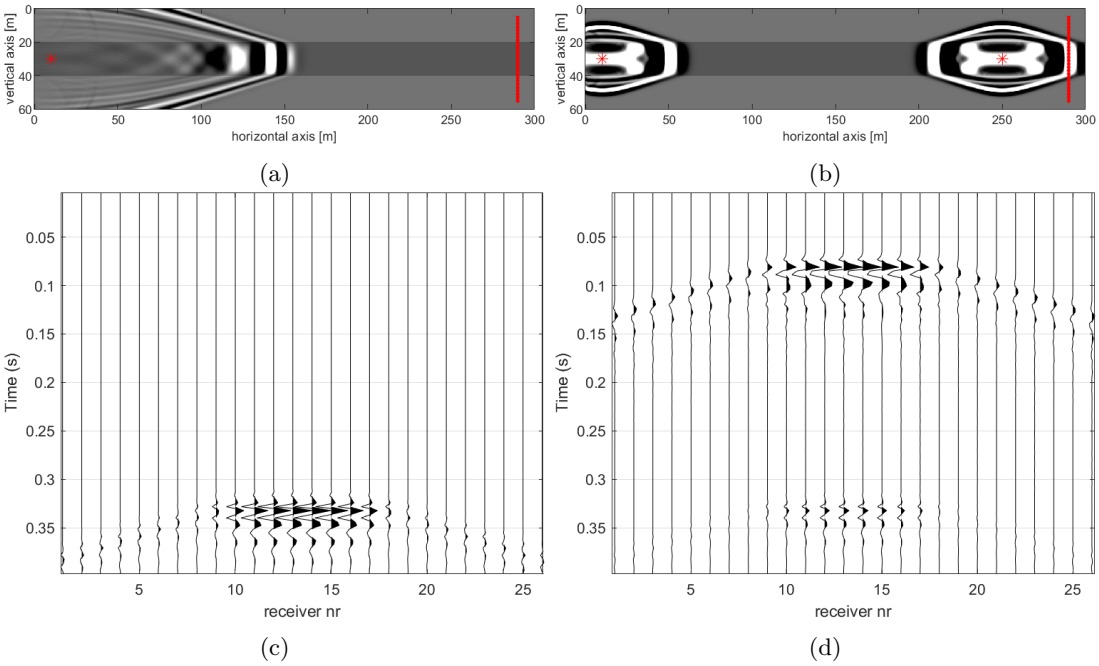


Figure 7: Example 6: Visualization of guide wave using evolving traces with (a)-(b) Ricker wavelet from sources placed at different positions on the model, (c)-(d) Seismic trace for scenario (a)-(b).

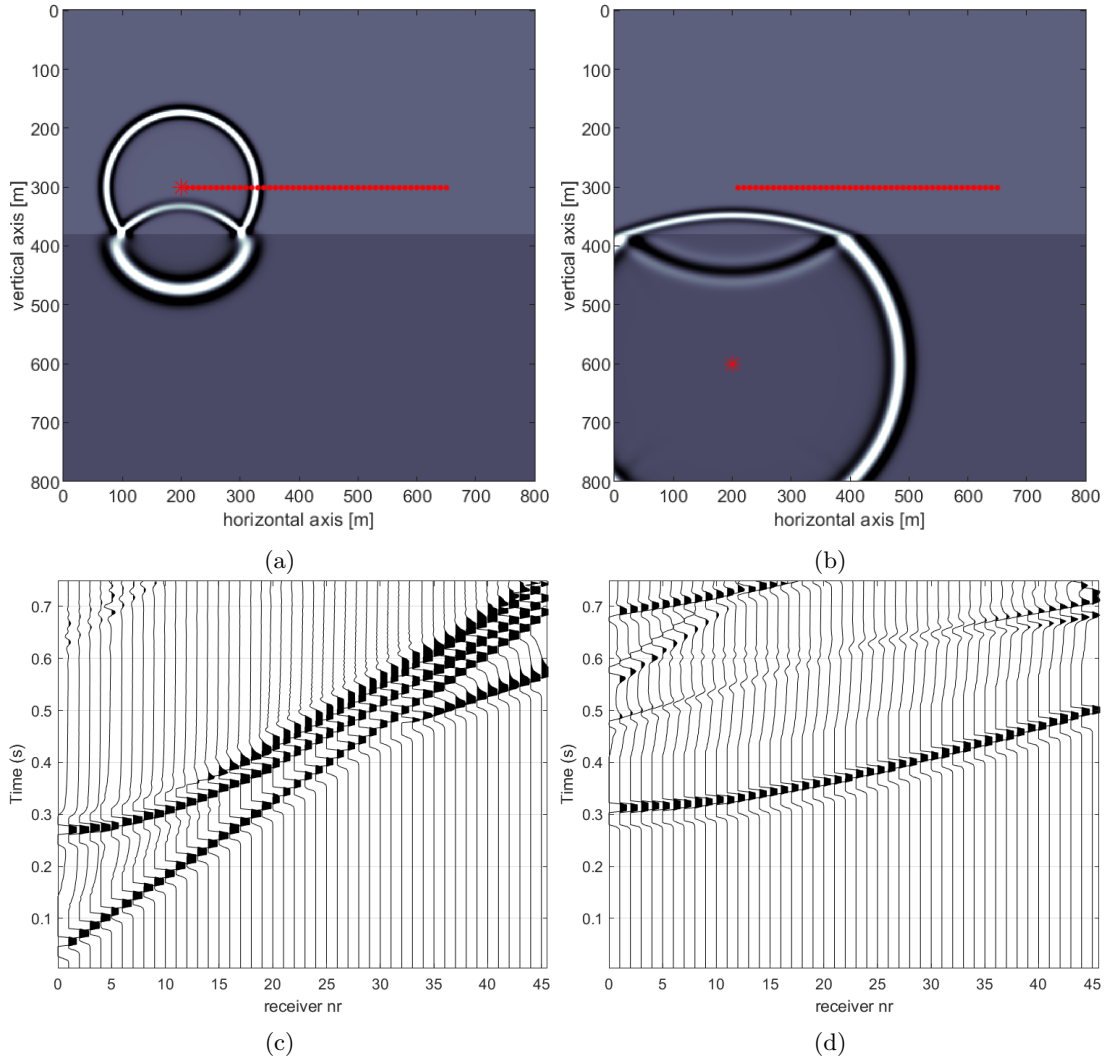


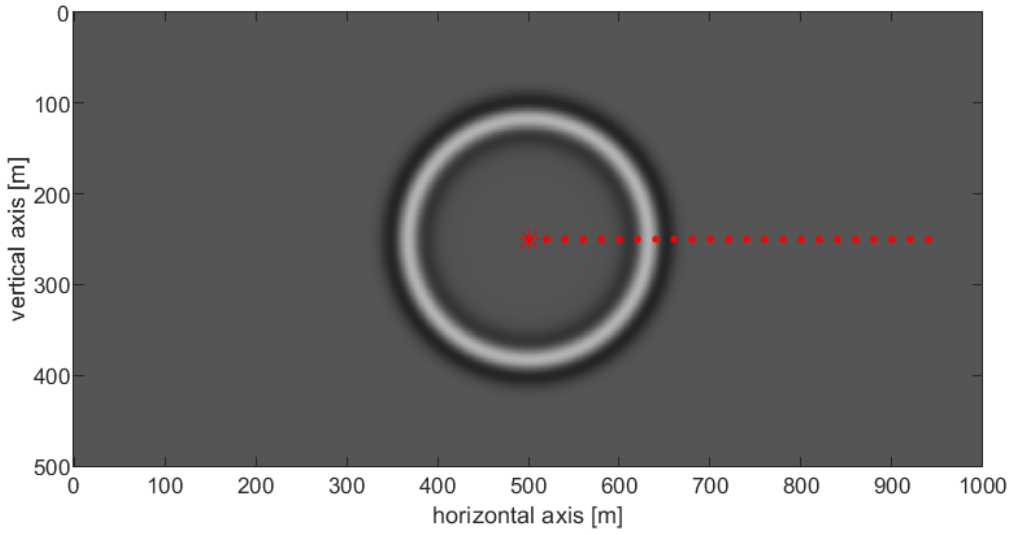
Figure 8: Example 7: Visualization of refraction using evolving traces with (a)-(b) Ricker wavelet from sources placed at regions with different wave velocity, (c)-(d) Seismic trace for scenario (a)-(b).

4.2 Exercise B2

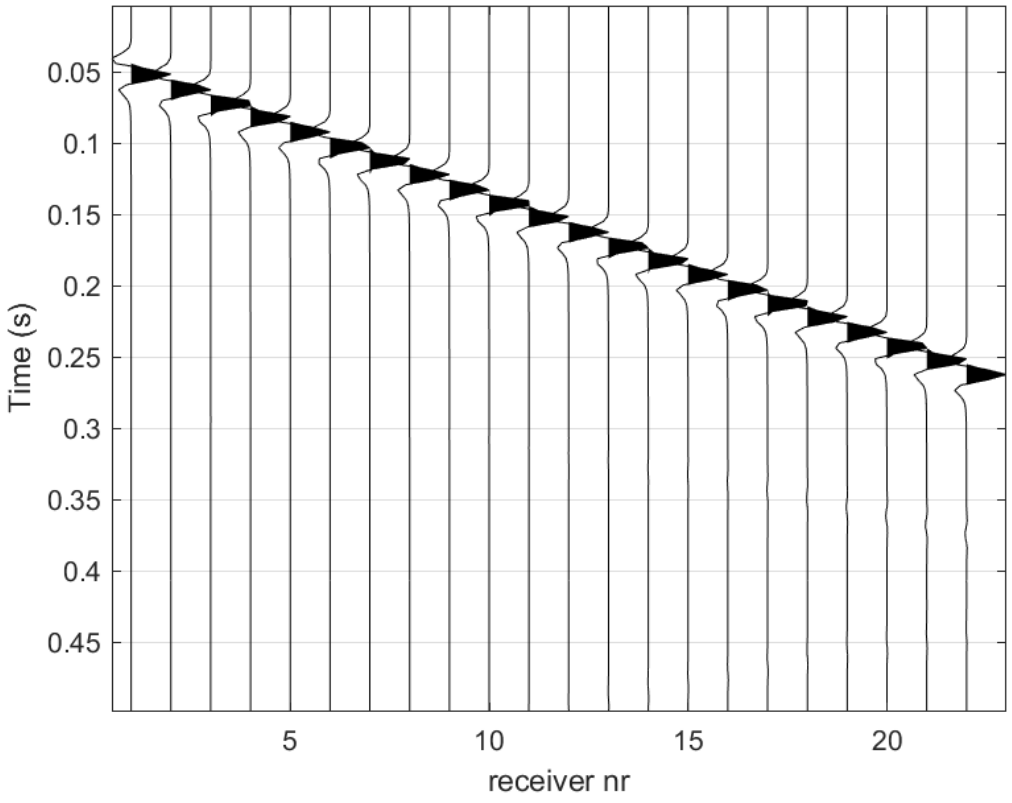
The simulation requires us to find the energy of the traces at increasing distance from the source. This requires us to design a model with the receivers places at increasing distance from the source location. Since the Ricker wavelet and sinusoidal wave excitation used are concentric in nature the direction / orientation of the receiver needs to satisfy two conditions,

- receivers are places in a line
- the line that receivers are placed passes through the source

The placement of the source and the receivers can be seen in figure. 9.The seismic traces obtained can be seen in figure. 9. The energy of the seismic traces compared with the theoretical attenuation is shown in figure. 10.



(a)



(b)

Figure 9: Exercise B2: (a) Visualization of placement of the source and the receivers (b) Seismic traces due to the excitation of the sources.

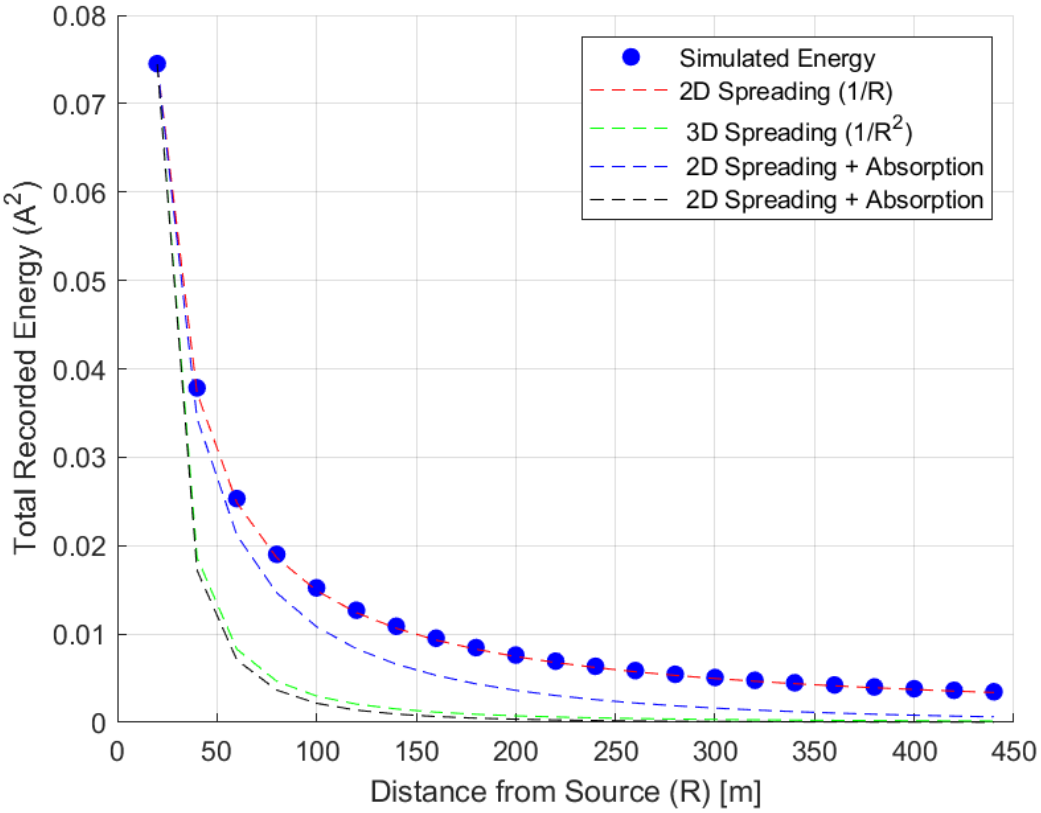
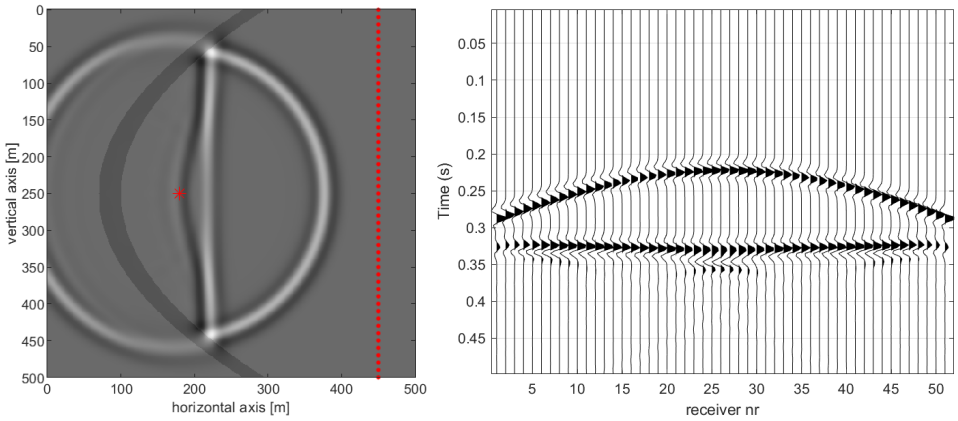


Figure 10: A plot the energy against the distance of the receivers from the source.

4.3 Exercise B3

An acoustic source emitting a Ricker wavelet that is placed exactly at the geometric focal point of the parabola ($x = 180\,\text{m}, z = 250\,\text{m}$).

According to ray theory, waves originating from the focus and striking the parabolic surface should reflect parallel to the principle axis, resulting in a planar wavefront. The result of the simulation of the above is shown in figure. 11.



(a) (b)

Figure 11: Exercise B3: (a) Visualization of placement of the source, receivers, and the planar wavefront produced due to the parabola. (b) Seismic traces due to the excitation of the sources.

4.4 Exercise B4

Due to refraction and reflection the acoustic waves can be filtered by using a large borders. This process is visualized in figure. 12.

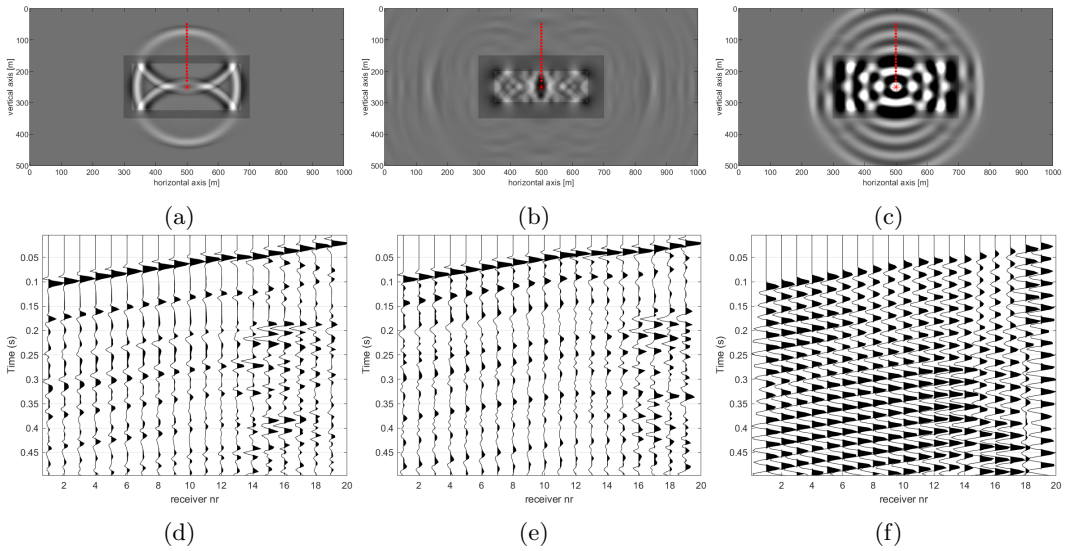


Figure 12: Exercise B4: (a)-(c) Visualization of placement of the source, and receivers (d)-(f) Seismic traces due to the excitation of the sources.

4.5 Exercise B5

A custom designed source model was simulated. The results of the simulation is shown in figure. 13.

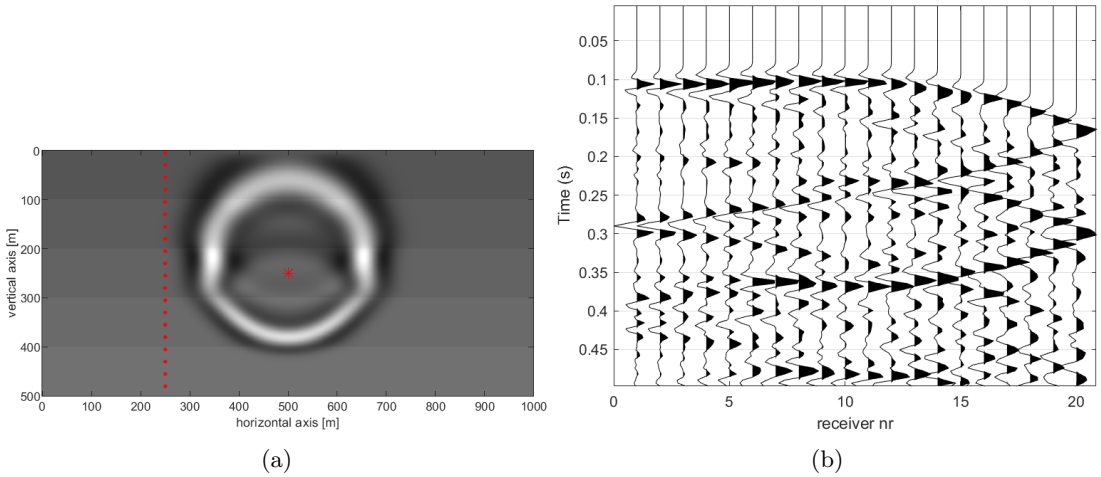


Figure 13: Exercise B5: (a) Visualization of placement of the source, and receivers(b) Seismic traces due to the excitation of the sources.

4.6 Exercise B6

The data of the accelerations during a person walking and traveling in a vehicle has been shown in the figure. 14.

(a)

(b)

Figure 14: Exercise B6: (a) Acceleration during a person walking (b) acceleration during an individual traveling in a vehicle.