F-K Analysis (1B)

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Seismic Wave

When seismic waves are generated at or near the surface of earth

- Body waves : P-wave, S-wave
  propagated through the whole body of the earth
- Surface waves : Rayleigh wave, Love wave
  propagated through along or near the surface of the earth

Body Waves

P-wave

Elastic wave
Can travel through a continuum (gases, liquids, solids)
Primary wave ← high velocity
Pressure wave ← alternating compressions and rarefactions
Longitudinal wave ← vibrations along or parallel to the travel direction

S-wave

Elastic wave
Cannot travel through a molten outer core of the Earth
Secondary wave ← slow velocity
Shear wave ← restoring force comes from shear effects
Transverse wave ← motion is perpendicular to the direction of wave propagation

Polarization and birefringence ← transverse wave properties
SH-wave : S-waves polarized in the horizontal plane
SV-wave : S-waves polarized in the vertical plane

Surface Wave

For a vertical seismic source

the generated surface wave is Rayleigh wave (ground roll)

Dispersion property

- surface waves exhibit
- body waves lack

Different **wavelength** - has different penetration **depth**
- propagates with different **velocity**

By analyzing the dispersion of surface waves,
near surface shear wave **velocity profile** can be obtained

Shear Wave Velocity Profile

By analyzing the dispersion of surface waves,
near surface shear wave **velocity profile** can be obtained

Shear wave velocity
→ shear modulus
→ direct indicator of **stiffness** (rigidity) of material
→ near surface **stiffness profile**

Dispersive Rayleigh Waves

Geometrical and mechanical characterization of the Earth's crust

Shallow geophysics – to estimate **soil stiffness**

Identification process

- experimental **dispersion curve**
- **inversion process** to estimate soil stiffness profile

Numerical simulation of
surface waves propagation
in layered linear elastic media

uni-dimensional model
– a regular horizontally stratified soil deposit
different modes of propagation
– soil heterogeneity

Assumption: distinct experimental dispersion curves
for the fundamental and for the higher **modes**

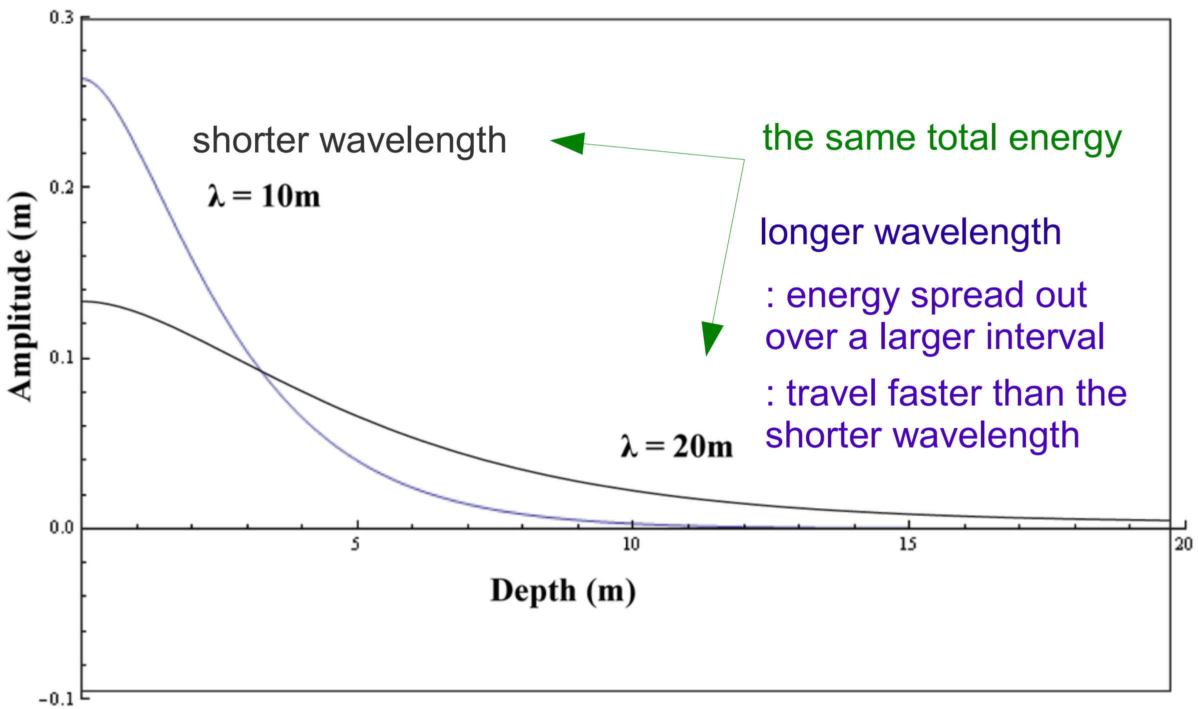
Dispersive Rayleigh Waves

SASW (Spectral Analysis of Surface Waves)
using a single pair of geophones - cost and time effective

Mode superposition effect requires
forward problem of surface wave propagation

Wavelength and Velocity

Surface waves of varying wavelengths
- penetrate to different depths
- propagate with different velocities



If earth materials' elastic parameters yield higher velocities with depth,

longer wavelength surface waves will travel faster than those with shorter wavelengths.

The variation of velocities with wavelength
→ infer critical information about the subsurface.

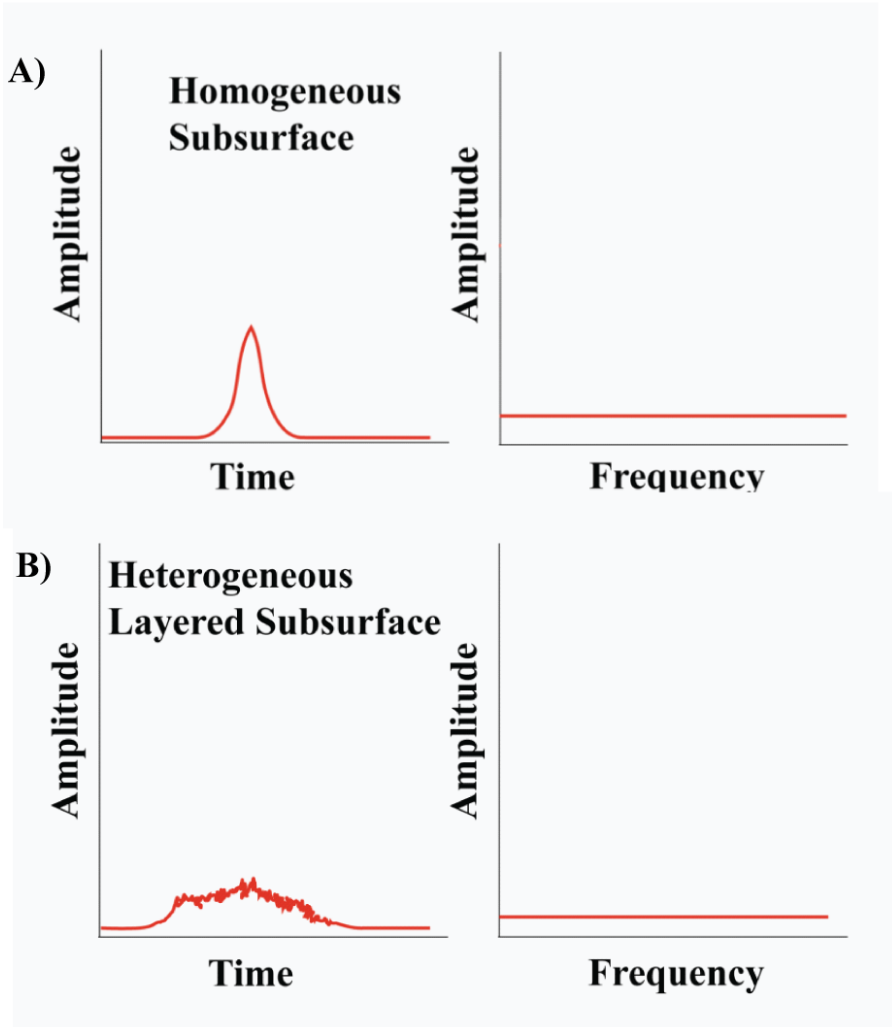
Spread out in Time Domain

A sharp impulse is made up of infinite frequency content in phase at one point.

If each frequency travels at the same speed, that peak will remain intact.

If each frequency travels at a different speed, that peak will spread out.

This spreading out is dispersion.



Wave Group

Longer wavelengths tend to travel faster:
for both group velocities and phase velocities.

A **wave group** consists of waves at varying wavelengths and frequencies. Individual waves of a wave group are usually generated at the same time, but tend to spread out within the group because each wavelet travels at a different speed.

A **group velocity** is basically the speed at which a wave group travels.
A **phase velocity** is the speed at which an individual wave travels, having its own characteristic wavelength and frequency.

Dispersion Curve (1)

For surface wave inversion,
phase velocities are used more often than group velocities
because it is **easier** to create a dispersion curve of phase velocities.

A **dispersion curve** is
a plot of **velocity** versus **frequency** or **wavelength**.

After the dispersion curve has been generated,
a surface wave inversion process is performed
to calculate the subsurface elastic properties.

The accuracy of the dispersion curve is crucial
in obtaining the correct subsurface elastic parameters from inversion.

The process of creating dispersion curves
from raw surface wave data (distance vs. time plot)
can be performed using two transformation processes.

The **wave-field** transformation
A modified **wave-field** transform

Dispersion Curve (2)

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References

[1] http://en.wikipedia.org/
[2] S. Foti, et. al, "Notes on fk analysis of surface waves", 2000