

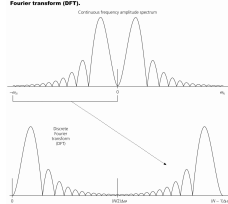
EAS 4803/8803 - Obs Seismology

Lec#7/8: Seismometers and Instrument Response

• Dr. Zhigang Peng, Spring 2013



Figure 8.4.4 Relation between frequency amplitude spectrum and discrete Fourier transform (DFT).



1/31/13

zpeng Seismology II

1

Last Time

- Coefficient representation for digital stages
- Pole-zero representation for digital stages
- Example of specifying an Analog Stage 1 (L22D short-period velocity seismometer)
- Effect of having poles and zeros in the transfer function
- Example Stage 0 specification
- Example of calculating analog stage 1 gain and phase

1/31/13

zpeng Seismology II

2

This time

- Structure for the SEED instrument response
- Compute gain and phase from poles and zeros
- How to remove instrument response



SEED Manual: http://www.iris.edu/manuals/SEEDManual_V2.4.pdf

1/31/13

zpeng Seismology II

3

Introducing SEED



- The **Standard for the Exchange of Earthquake Data** (SEED) is an international standard format for the exchange of digital seismological data.
- SEED was designed for use by the earthquake research community, primarily for the exchange between institutions of unprocessed earth motion data.
- It is a format for digital data measured at one point in space and at equal intervals of time.
- SEED helps seismologists who record, share, and use seismological data.
- By providing a standard, SEED makes transmitting, receiving, and processing earthquake data easier and more accurate.

1/31/13

zpeng Seismology II

4

Blockettes

- Each control header is made up of a sequence of **blockettes** — data structures that contain a type identifier, length, and sequence of data fields specific to the blockette type.
- Blockettes may be either ASCII formatted (in control headers) or unformatted binary (in data records).
- Each data field contains auxiliary information on one topic, and may be either fixed or variable in length.

1/31/13

zpeng Seismology II

5

Typically used Blockette for instrument response

- Channel Identifier Blockette [52]
- Response (Poles & Zeros) Blockettes [53]
- Response (Coefficients) Blockettes [54]
- Decimation Blockettes [57]
- Channel Sensitivity/Gain Blockettes [58]

1/31/13

zpeng Seismology II

6

Channel Identifier Blockette [52]

```
# << IRIS SEED Reader, Release 4.6 >>
## ===== CHANNEL RESPONSE DATA =====
B050F03 Station: PKD
B050F16 Network: BK
B052F03 Location: ??
B052F04 Channel: HHZ
B052F22 Start date: 1996,250,16:28:00
B052F23 End date: 2004,167,00:00:00
```

http://geophysics.eas.gatech.edu/people/zpeng/Teaching/ObsSeis_2013/misc/RESP.BK.PKD..HHZ

1/31/13

zpeng Seismology II

7

Response (Poles & Zeros) Blockettes [53]

```
# -----
# +-----+-----+-----+-----+
# | Response (Poles & Zeros), PKD ch HHZ |
# +-----+-----+-----+-----+
#
B053F03 Transfer function type: A [Laplace Transform (Rad/sec)]
B053F04 Stage sequence number: 1
B053F05 Response in units lookup: M/S - Velocity in Meters Per Second
B053F06 Response out units lookup: V - Volts
B053F07 A0 normalization factor: 4.86246E+07 How to get this?
B053F08 Normalization frequency: 1
B053F09 Number of zeroes: 2
B053F14 Number of poles: 5
#
# Complex zeroes:
# i real imag real_error imag_error
B053F10-13 0 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
B053F10-13 1 0.000000E+00 0.000000E+00 0.000000E+00 0.000000E+00
#
# Complex poles:
# i real imag real_error imag_error
B053F15-18 0 -3.702370E-02 3.702440E-02 0.000000E+00 0.000000E+00
B053F15-18 1 -3.702370E-02 -3.702440E-02 0.000000E+00 0.000000E+00
B053F15-18 2 -1.187520E+02 4.234880E+02 0.000000E+00 0.000000E+00
B053F15-18 3 -1.187520E+02 -4.234880E+02 0.000000E+00 0.000000E+00
B053F15-18 4 -2.513270E+02 0.000000E+00 0.000000E+00 0.000000E+00
#
```

STS-2 broadband velocity sensor

1/31/13

zpeng Seismology II

8

Most common way of representing response information

- Poles and zeros (PAZ)
- Discrete amplitude and phase values (FAP)
- Individual parameters (free period, ADC gain etc)
- Polynomials
- Combination of the above
- Time domain filter coefficients

1/31/13

zpeng Seismology II

9

Compute gain and phase from poles and zeros

- Write the transfer function $H(s)$ in terms of poles and zeros format.
- Substitute s with the value $i\omega = i 2\pi f$.
- Compute the amplitude and phase.
- Evaluate at f_0 to get the normalization factor A_0 .

1/31/13

zpeng Seismology II

10

Using Matlab to get the instrument response from poles and zeros

```
>> zeros = [0 0]';
>> poles = [pole1 pole2 pole3 pole4 pole5]';
>> sys = zp2tf(zeros,poles,1)
```

Zero/pole/gain:

s^2

(s+251.3) (s² + 0.07405s + 0.002742) (s² + 237.5s + 1.934e05)

1/31/13

zpeng Seismology II

11

Using Matlab to get the instrument response from poles and zeros

```
>> [n,d] = zp2tf(zeros,poles,1);

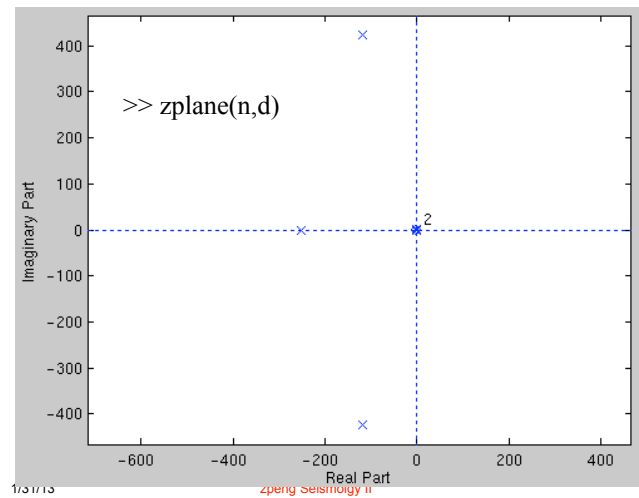
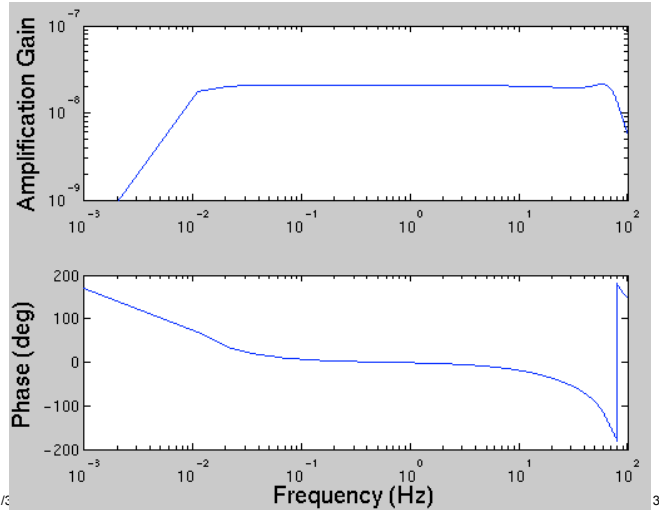
n=0 0 0 1 0 0
d=1.0e+07 * [0.0000 0.0000 0.0253 4.8636 0.3601
0.0133]
```

```
>> W = ff.*2.*pi;
>> H = freqs(n,d,W);
```

1/31/13

zpeng Seismology II

12



Obtaining the SEED ASCII response file

- Request data from IRIS or other data center in SEED format.
- Using rdseed command to extract the response file:
 - rdseed -R -f SEED_file
- Using rdseed command to extract the data in Seismic Analysis Code (SAC) format:
 - rdseed -d -o 1 -f SEED_file

<http://www.iris.edu/manuals/>
<http://geophysics.eas.gatech.edu/classes/SAC>

1/31/13

zpeng Seismology II

15

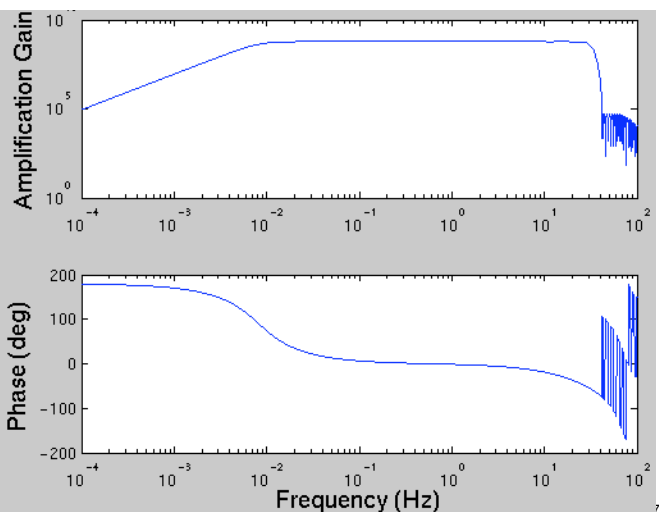
Obtain the response information using evalresp

- evalresp: evaluate response information and output to ASCII files using rdseed produced RESP files
 - USAGE: evalresp STALST CHALST YYYY DAY MINFREQ MAXFREQ NFREQ [options]
 - evalresp PKD HHZ 2002 302 0.0001 100 5000 -f RESP.BK.PKD..HHZ
 - Command stn chan year jday minfreq maxf nfreq filename
- Output: AMP.BK.PKD..HHZ and PHASE.BK.PKD..HHZ
 - Two column ascii data for the amplitude and phase information of the instrument response

1/31/13

zpeng Seismology II

16



Removing instrument response using SAC's transfer function

- SAC > help transfer
- Example command:


```
r BK.PKD.HHZ.SAC # read the SAC data
rmean           # remove the mean
taper           # apply a hanning taper with 0.05 width
transfer from polezero subtype BK_PKD.PZ to none
# option polezero filename to default
FREQLIMITS 0.001 0.002 30 40
# apply a taper in the frequency domain for the output
w append .vel # save the output
```

1/31/13

zpeng Seismology II

18

Using “polezero” option for the “transfer” command

- File BK_PKD.PZ
 - ZEROS 2
 - 0.000000E+00 0.000000E+00
 - 0.000000E+00 0.000000E+00
 - POLES 5
 - -3.702370E-02 3.702440E-02
 - -3.702370E-02 -3.702440E-02
 - -1.187520E+02 4.234880E+02
 - -1.187520E+02 -4.234880E+02
 - -2.513270E+02 0.000000E+00
 - **CONSTANT 2.948878e+16 ($S_d \times A_0$)**

1/31/13

zpeng Seismology II

19

Another way of using “gsac” to remove the instrument response

- Use evalresp command to extract the amplitude and phase response of the instrument
- Use the following command in “gsac”:
 - transfer from eval subtype AMP.BK.PKD.HHZ PHASE.BK.PKD.HHZ to none FREQLIMITS 0.001 0.002 30 40



Robert B. Herrmann, SLU

<http://www.eas.slu.edu/People/RBHerrmann/CPS330.html>

1/31/13

zpeng Seismology II

20

The third option (directly using the RESP file, not working yet)

- SAC > help transfer
- Example command:

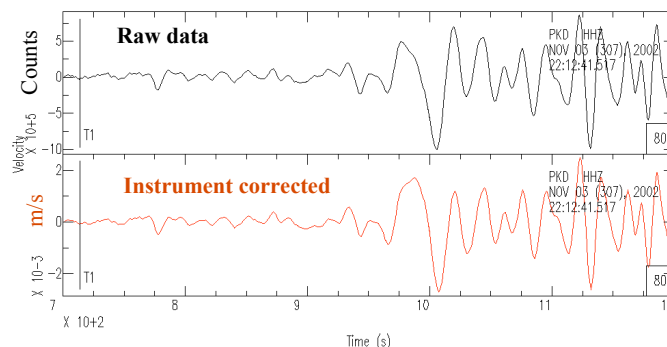

```
r BK.PKD.HHZ.SAC # read the SAC data
rmean # remove the mean
taper # apply a hanning taper with 0.05 width
transfer from EVALRESP FNAME RESP.BK.PKD..HHZ to vel
# option response file name output to vel
FREQLIMITS 0.001 0.002 30 40
# apply a taper in the frequency domain for the output
div 6.064580E+08 # manually divide the sensitivity (!)
w append .vel # save the output
```

1/31/13

zpeng Seismology II

21

Example output

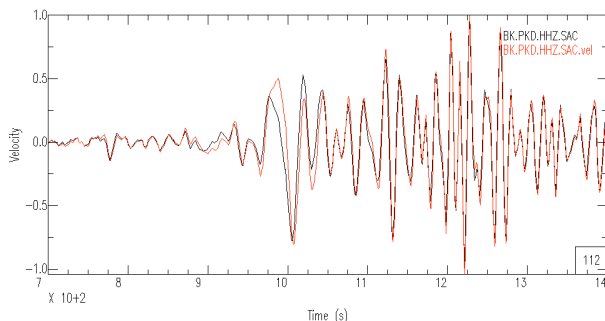


1/31/13

zpeng Seismology II

22

Example output



1/31/13

zpeng Seismology II

23

Adding zeros in the pole-zero file

- If we add one more zeros, the de-convolved input function would be displacement.

$$T_{vel}(j\omega) = \frac{Output(j\omega)}{Input_{vel}(j\omega)}$$

$$Input_{vel}(j\omega) = j\omega \cdot Input_{disp}(j\omega)$$

$$T_{vel}(j\omega) = \frac{Output(j\omega)}{j\omega \cdot Input_{disp}(j\omega)}$$

$$T_{disp}(j\omega) = \frac{Output(j\omega)}{Input_{disp}(j\omega)} = j\omega \cdot T_{vel}(j\omega)$$

1/31/13

zpeng Seismology II

24

Next Time

- Data management and basic data processing tools
- Waveform stacking
- Array analysis