EAS 4803/8803 - Obs Seismology
Lec#9/10: Seismometers and Instrument Response

- Dr. Zhigang Peng, Spring 2019

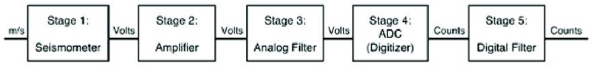
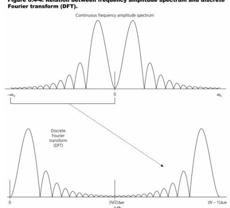


Figure 6.4-4: Relation between frequency amplitude spectrum and discrete Fourier transform (DFT).



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 O specification
- Example of calculating analog stage 1 gain and phase

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

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.

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.

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]

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

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
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
#
```

How to get this?

STS-2 broadband velocity sensor

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

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 .

Using Matlab to get the instrument response from poles and zeros

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

Zero/pole/gain:

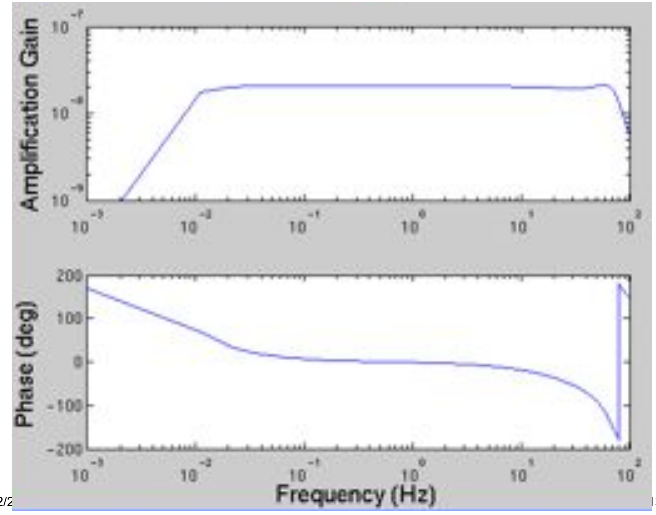
```
                           s^2
-----------------------------------------------------------------
(s+251.3) (s^2  + 0.07405s + 0.002742) (s^2  + 237.5s + 1.934e05)
```

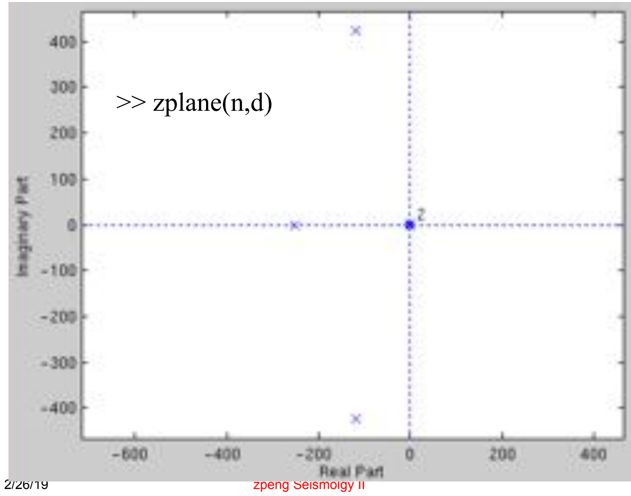

Using Matlab to get the instrument response from poles and zeros

```
>> [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);
```





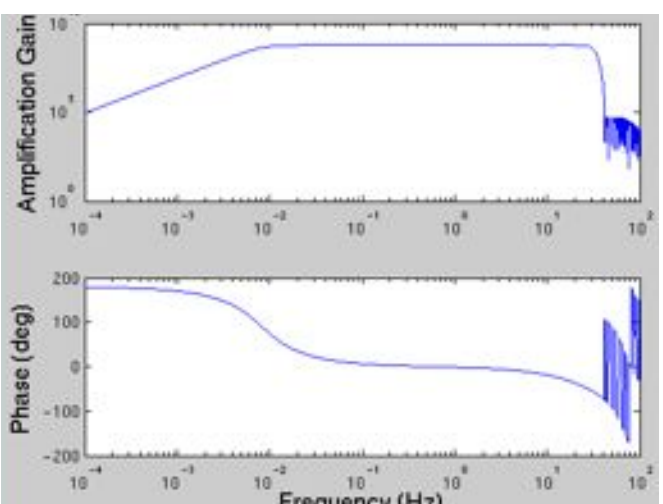
Obtaining the SEED ASCII response file

- 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

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



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
```

Using "polezero" option for the "transfer" command

- File BK_PZK.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 x A_0)

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

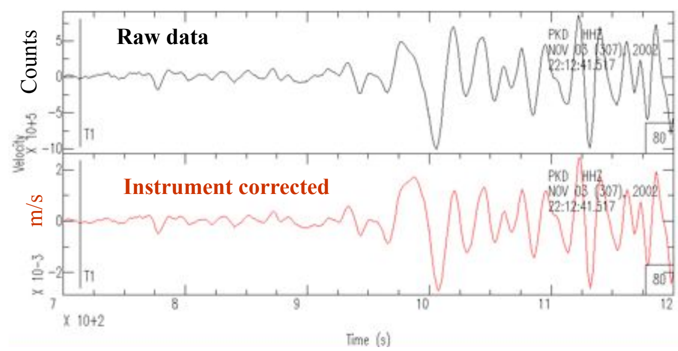
Robert B. Herrmann, SLU
http://www.eas.slu.edu/People/RBHerrmann/CPS330.html

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

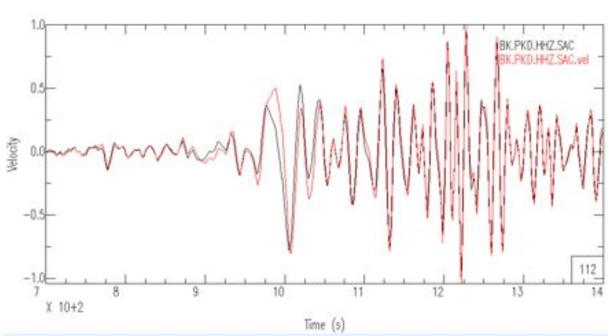
- SAC > help transfer
- Example command:

```
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
```


Example output



Example output



Adding zeros in the pole-zero file

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

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

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

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

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

Next Time

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