

<b>Title</b>	<b>Interpreting Poles and Zeros from SEED headers</b>
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## 1 Aim

The complex transfer function (or the related complex frequency response) of the analog part of a seismograph is a rational function of frequency. Such functions can be specified by corner frequencies and damping constants, by polynomial coefficients, or by their poles and zeros. The latter method is chosen in the IRIS SEED data volumes. For each data channel of each station, the data header contains a list of poles and zeros of the transfer function together with some auxiliary information. IRIS supplies a software library 'evalresp' for extracting and interpreting these parameters. The exercise aims at making you familiar with interpreting poles and zeros in terms of the amplitude response versus frequency.

## 2 Task

Interpret one or more of the annexed SEED headers with respect to the analog part of the seismograph. Sketch the amplitude response for one of the stations as a Bode-diagram on double logarithmic paper. (The digital part is usually of minor interest since it is supposed to have a flat amplitude response and zero phase delay.) Does the header describe a very broadband, broadband or narrowband system? Note that the answer does not only depend on the mathematical form of the response but also on the definition of the input signal - displacement, velocity or acceleration. A broadband seismograph is supposed to have a broadband response to velocity but a broadband accelerometer has a broadband response to acceleration. Be careful with the units - some headers refer to Hertz rather than radians/sec. Check also whether the poles and zeros refer to the Laplace transform or Fourier transform. Can you guess which type of sensor is used? Are the constants nominal or were they determined from an individual calibration?

A little computer program **polzero** in BASIC can be downloaded from either [www.software-for-seismometry.de](http://www.software-for-seismometry.de) or by right mouse click on this program name in the NMSOP-2 content overview folder *Download Programs & Files*. It will do for you the numerical conversions and plot the amplitude response. Use this program to analyze some more of the SEED headers. The stations are:

KIP (Kipapa, Hawaii)  
 KONO (Kongsberg, Norway)  
 KMI (Kunming, China)  
 PFO (Pinion Flat Observatory, California)  
 XAN (Xi'an, China)

## 3 Annex

SEED headers for stations KIP, KONO, KMI, PFO and XAN

## KIP

```

:-----:
RESP.G.KIP..LHE
:-----:
#          << IRIS SEED Reader, Release 4.16 >>
#
#          ===== CHANNEL RESPONSE DATA =====
B050F03   Station:      KIP
B050F16   Network:     G
B052F03   Location:    ??
B052F04   Channel:    LHE
B052F22   Start date:  1988,147
B052F23   End date:   No Ending Time
#
#          +-----+-----+-----+-----+
#          |                                     |
#          |                                     |
#          |                                     |
#          +-----+-----+-----+-----+
B053F03   Transfer function type:      B [Analog (Hz)]
B053F04   Stage sequence number:      1
B053F05   Response in units lookup:   M/S - Velocity
B053F06   Response out units lookup:  V - Volts
B053F07   A0 normalization factor:   25.0743
B053F08   Normalization frequency:   0.01
B053F09   Number of zeroes:          2
B053F14   Number of poles:           4
#          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 -1.964190E-03 1.964190E-03 0.000000E+00 0.000000E+00
B053F15-18 1 -1.964190E-03 -1.964190E-03 0.000000E+00 0.000000E+00
B053F15-18 2 -3.117500E+00 3.909120E+00 0.000000E+00 0.000000E+00
B053F15-18 3 -3.117500E+00 -3.909120E+00 0.000000E+00 0.000000E+00
#
#          +-----+-----+-----+-----+
#          |                                     |
#          |                                     |
#          |                                     |
#          +-----+-----+-----+-----+
B058F03   Stage sequence number:      1
B058F04   Gain:                    2.398000E+03
B058F05   Frequency of gain:         1.000000E-02 HZ
B058F06   Number of calibrations:    0
#
#          +-----+-----+-----+-----+
#          |                                     |
#          |                                     |
#          |                                     |
#          +-----+-----+-----+-----+
B053F03   Transfer function type:      B [Analog (Hz)]
B053F04   Stage sequence number:      2
B053F05   Response in units lookup:   V - Volts
B053F06   Response out units lookup:  V - Volts
B053F07   A0 normalization factor:   15593.8
B053F08   Normalization frequency:   0.01
B053F09   Number of zeroes:          0
B053F14   Number of poles:           6
#          Complex zeroes:
#          i real          imag          real_error  imag_error
#          Complex poles:
#          i real          imag          real_error  imag_error
B053F15-18 0 -4.832580E+00 1.273240E+00 0.000000E+00 0.000000E+00
B053F15-18 1 -4.832580E+00 -1.273240E+00 0.000000E+00 0.000000E+00
B053F15-18 2 -3.538230E+00 3.529300E+00 0.000000E+00 0.000000E+00
B053F15-18 3 -3.538230E+00 -3.529300E+00 0.000000E+00 0.000000E+00
B053F15-18 4 -1.295000E+00 4.829390E+00 0.000000E+00 0.000000E+00
B053F15-18 5 -1.295000E+00 -4.829390E+00 0.000000E+00 0.000000E+00
#

```

## KONO

```

:.....:
RESP.IU.KONO.10.LHE
:.....:
#          << IRIS SEED Reader, Release 4.16 >>
#
#          ===== CHANNEL RESPONSE DATA =====
B050F03   Station:      KONO
B050F16   Network:     IU
B052F03   Location:    10
B052F04   Channel:     LHE
B052F22   Start date:  1999,040,13
B052F23   End date:    No Ending Time
#
#          +-----+
#          +           | Response (Poles & Zeros), KONO ch LHE |
#          +-----+
#
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:    7.1367E+07
B053F08   Normalization frequency:    0.1
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 -3.701000E-02 3.701000E-02 0.000000E+00 0.000000E+00
B053F15-18 1 -3.701000E-02 -3.701000E-02 0.000000E+00 0.000000E+00
B053F15-18 2 -1.979000E+02 1.979000E+02 0.000000E+00 0.000000E+00
B053F15-18 3 -1.979000E+02 -1.979000E+02 0.000000E+00 0.000000E+00
B053F15-18 4 -9.111000E+02 0.000000E+00 0.000000E+00 0.000000E+00
#
#          +-----+
#          +           | Channel Gain, KONO ch LHE |
#          +-----+
#
B058F03   Stage sequence number:      1
B058F04   Gain:                      2.026400E+04
B058F05   Frequency of gain:          2.000000E-02 HZ
B058F06   Number of calibrations:     0
#
#          +-----+
#          +           | Response (Coefficients), KONO ch LHE |
#          +-----+
#
B054F03   Transfer function type:      D
B054F04   Stage sequence number:      2
B054F05   Response in units lookup:   V - Volts
B054F06   Response out units lookup:  COUNTS - Digital Counts
B054F07   Number of numerators:        0
B054F10   Number of denominators:     0
#
#          +-----+
#          +           | Decimation, KONO ch LHE |
#          +-----+
#
B057F03   Stage sequence number:      2
B057F04   Input sample rate:          5.120000E+03
B057F05   Decimation factor:          1
B057F06   Decimation offset:          0
B057F07   Estimated delay (seconds):   0.000000E+00

```

## KMI

```

#
#
#
#
# ***** CHANNEL RESPONSE DATA *****
#
#      Station:      KMI
#      Network:      CD
#      Location:     ??
#      Channel:      LHZ
#      Start date:   1986,159
#      End date:     1996,108
#
# -----
#                +-----+
#                |                |
#                | Response (Poles & Zeros), KMI ch LHZ |
#                |                |
#                +-----+
#
#      B053F03       Transfer function type:         A [Laplace Transform (Rad/sec)]
#      B053F04       Stage sequence number:         1
#      B053F05       Response in units lookup:      M - Earth Displacement in Meters
#      B053F06       Response out units lookup:    COUNTS - Digital Counts
#      B053F07       A0 normalization factor:      0.000492889
#      B053F08       Normalization frequency:      0.04
#      B053F09       Number of zeroes:             4
#      B053F14       Number of poles:              10
#
#      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
#      B053F10-13   2 0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
#      B053F10-13   3 0.000000E+00  0.000000E+00  0.000000E+00  0.000000E+00
#
#      Complex poles:
#                i   real      imag      real_error  imag_error
#      B053F15-18   0 -2.221000E-01  2.221000E-01  0.000000E+00  0.000000E+00
#      B053F15-18   1 -2.221000E-01 -2.221000E-01  0.000000E+00  0.000000E+00
#      B053F15-18   2 -7.405000E-03  7.405000E-03  0.000000E+00  0.000000E+00
#      B053F15-18   3 -7.405000E-03 -7.405000E-03  0.000000E+00  0.000000E+00
#      B053F15-18   4 -2.023000E-01  5.420000E-02  0.000000E+00  0.000000E+00
#      B053F15-18   5 -2.023000E-01 -5.420000E-02  0.000000E+00  0.000000E+00
#      B053F15-18   6 -1.481000E-01  1.481000E-01  0.000000E+00  0.000000E+00
#      B053F15-18   7 -1.481000E-01 -1.481000E-01  0.000000E+00  0.000000E+00
#      B053F15-18   8 -5.420000E-02  2.023000E-01  0.000000E+00  0.000000E+00
#      B053F15-18   9 -5.420000E-02 -2.023000E-01  0.000000E+00  0.000000E+00
#
#                +-----+
#                |                |
#                | Channel Sensitivity, KMI ch LHZ |
#                |                |
#                +-----+
#
#      B058F03       Stage sequence number:         0
#      B058F04       Sensitivity:                   1.800000E+09
#      B058F05       Frequency of sensitivity:      4.000000E-02 HZ
#      B058F06       Number of calibrations:        0
#
#
#
#

```

## PFO

```

.....
RESP.TS.PFO..LHZ
.....
#           << IRIS SEED Reader, Release 4.16 >>
#
#           ===== CHANNEL RESPONSE DATA =====
B050F03    Station:      PFO
B050F16    Network:      TS
B052F03    Location:     ??
B052F04    Channel:      LHZ
B052F22    Start date:   1990,304
B052F23    End date:     No Ending Time
#
#           =====
#           +-----+
#           | Response (Poles & Zeros),  PFO ch LHZ |
#           +-----+
#
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:  3948.58
B053F08    Normalization frequency:  0.02
B053F09    Number of zeroes:          2
B053F14    Number of poles:          4
#           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 -1.234000E-02  1.234000E-02  0.000000E+00  0.000000E+00
B053F15-18  1 -1.234000E-02 -1.234000E-02  0.000000E+00  0.000000E+00
B053F15-18  2 -3.918000E+01  4.912000E+01  0.000000E+00  0.000000E+00
B053F15-18  3 -3.918000E+01 -4.912000E+01  0.000000E+00  0.000000E+00
#
#           +-----+
#           | Channel Gain,  PFO ch LHZ |
#           +-----+
#
B058F03    Stage sequence number:    1
B058F04    Gain:                     2.122720E+03
B058F05    Frequency of gain:         2.000000E-02 HZ
B058F06    Number of calibrations:    0
#
#           +-----+
#           | Response (Coefficients),  PFO ch LHZ |
#           +-----+
#
B054F03    Transfer function type:    D
B054F04    Stage sequence number:     2
B054F05    Response in units lookup:   V - Volts
B054F06    Response out units lookup:  COUNTS - Digital Counts
B054F07    Number of numerators:       43
B054F10    Number of denominators:     0
#           Numerator coefficients:
#           i, coefficient,  error
B054F08-09  0 -3.557280E-09 -7.114550E-11
B054F08-09  1  3.273000E-06  6.546030E-08
B054F08-09  2 -3.791030E-04 -7.582060E-06
B054F08-09  3 -2.870530E-03 -5.741070E-05
B054F08-09  4 -2.949110E-03 -5.898210E-05
B054F08-09  5  3.191820E-03  6.383630E-05
B054F08-09  6 -2.121360E-03 -4.242730E-05
B054F08-09  7 -5.931070E-04 -1.186210E-05
B054F08-09  8  4.816940E-03  9.633870E-05

```

XAN

```

:.....:
RESP.IC.XAN..LHE
:.....:
#
# << IRIS SEED Reader, Release 4.16 >>
#
# ----- CHANNEL RESPONSE DATA -----
B050F03 Station: XAN
B050F16 Network: IC
B052F03 Location: ??
B052F04 Channel: LHE
B052F22 Start date: 1992,334
B052F23 End date: 1995,149
#
# =====
# +-----+
# + | Response (Poles & Zeros), XAN ch LHE |
# +-----+
#
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: 5.96806E+07
B053F08 Normalization frequency: 0.02
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 -3.564700E-02 -3.687900E-02 0.000000E+00 0.000000E+00
B053F15-18 1 -3.564700E-02 3.687900E-02 0.000000E+00 0.000000E+00
B053F15-18 2 -2.513300E+02 0.000000E+00 0.000000E+00 0.000000E+00
B053F15-18 3 -1.310400E+02 -4.672900E+02 0.000000E+00 0.000000E+00
B053F15-18 4 -1.310400E+02 4.672900E+02 0.000000E+00 0.000000E+00
#
# +-----+
# + | Channel Gain, XAN ch LHE |
# +-----+
#
B058F03 Stage sequence number: 1
B058F04 Gain: 1.500000E+03
B058F05 Frequency of gain: 2.000000E-02 HZ
B058F06 Number of calibrations: 0
#
# +-----+
# + | Response (Coefficients), XAN ch LHE |
# +-----+

```

### 3 Solutions

- KIP** velocity very broadband, lower corner 360 s, upper corner 0.2 s  
Obviously an older STS1-VBB seismometer. No extra filters.  
Nominal parameters.
- KONO** velocity broadband, lower corner 120 s, upper corner 44.5 Hz  
Must be an STS2 or a CMG3-T. Nominal parameters. Additional  
low-pass Filter at 145 Hz.
- KMI** narrowband LP as a displacement sensor, but better characterized as  
a long-period acceleration sensor. Response is flat to acceleration  
from 30 s to 600 s. The sensor must be an old STS1 (20 s). A 6<sup>th</sup>-order  
Butterworth low-pass filter limits the bandwidth at 30 s; this would  
today be done with digital filters in the recorder. Parameters are nominal.
- PFO** velocity very broadband, lower corner 360 s, upper corner 0.1 s.  
A modern STS1-VBB. No extra filters. Nominal parameters.
- XAN** velocity broadband, lower corner 120 s, upper corner 44 Hz.  
Probably an STS2 or a CMG3-T seismometer. Additional low-pass  
filter at 77 Hz. Parameters were probably measured.