

## Appendix C

# Seismometer response

Response instruments used during the TOR experiment and Seismic Handler velocity restitution filter. The instrument response list was collected mainly by Silke Hock and Joachim Ritter.

Host, digitizer, sensor and response file:

GFZ	Reftek	Guralp 3T	T_V_GREF3T.FLF
GFZ	Reftek	Guralp 40T	T_V_GREF40T.FLF
GFZ	Reftek	STS-2	T_V_GREFSTS2.FLF
GFZ	Reftek	MARK L4 1s	T_V_GREFMARK.FLF
GFZ	Mars88	MARK L4 1s	not available
Bochum	PDAS	MARK L4 1s	T_V_BPDASMARK.FLF
Zuerich	Mars88	Lennartz LE-3D 1s	T_V_ZMARSLE1.FLF
Poland	PSS	MARK L4 1s	T_V_POLMARK1.FLF
Poland	PSS	MARK L4 0.5s	T_V_POLMARK2.FLF
Swedish Orion		MARK L4 0.5s	T_V_SORIMARK2.FLF
Swedish Orion		Lennartz LE-3D 1s	T_V_SORILE1.FLF
Swedish Orion		Lennartz LE-3D 5s	T_V_SORILE5.FLF
Leipzig	Reftek	Guralp ESP	T_V_LREFESP.FLF

permanent stations:

GRSN	German Regional Seismic Network		
	Quanterra STS-2		T_V_GRSN.FLF
GRF	Greafenberg Array		
	STS-1		T_V_GRF.FLF

Gains:

GFZ Reftek with Guralp 3T

to correct the different values for the generator constants of  
of the seismometers we used an average value !

gain: average gain 1.262 - 1.284

used APPROXIMATION: 1.273

error < 2%

## GFZ Reftek with Guralp 40T

to correct the different values for the generator constants of  
of the seismometers we used an average value !  
gain: average gain 2.371 - 2.394  
used APPROXIMATION: 2.3835  
error < 2%

## GFZ Reftek with STS-2

to correct the different values for the generator constants of  
of the seismometers we used an average value !  
STS-2 manual  
used APPROXIMATION: 1.271  
error < 2%

## GFZ Reftek with MARK L4-3D 1s

to correct the different values for the generator constants of  
of the seismometers we used an average value !  
data provided by J. Bribach, average by J. Ritter  
used APPROXIMATION: 11.16 (incl. gain setting 1 at Reftek)  
error < 10%, mostly < 3%

## GFZ Mars88 with MARK L4-3D 1s

not available

## Bochum PDAS with MARK L4-3D 1s

to correct the different values for the generator constants of  
of the seismometers we used an average value !  
the approximation should be valid within +/- 5%

## Zuerich Mars88 with Lennartz LE-3D 1s

1 count = 1 uV  
generator constant: 400 V/m/s  
0.4 count = 1 nm/s  
factor 2.5 for count > nm/s

## Poland PSS with MARK L4-3D 1s

for the amplitudes an average value is taken  
data provided by S.Hock and M.Zuchniak  
error bars: unknown

## Poland PSS with MARK L4-3D 0.5s

for the amplitudes an average value is taken  
data provided by S.Hock and M.Zuchniak  
error bars: unknown

## Swedish Orion with MARK L4-3D 0.5

LSB : 203 nV/LSB  
generator constant: 6.9 V/inch/s

1 inch = 0.0254 m  
 no further preamplification  
 source: S.Hock  
 error bars: unknown

Swedish Orion with Lennartz LE-3D 1s  
 LSB : 203 nV/LSB  
 generator constant: 400 V/m/s  
 no further preamplification  
 source: S.Hock  
 error bars: unknown

Swedish Orion with Lennartz LE-3D 5s  
 LSB : 203 nV/LSB  
 generator constant: 400 V/m/s  
 no further preamplification  
 source: S.Hock  
 error bars: unknown

Leipzig Reftek with Guralp ESP  
 Reftek gain 1.0  
 average generator constant used  
 source: S. Hock  
 error < 3%

GRSN  
 Quanterra data logger with STS-2 seismometer  
 source:<http://www-seismo.hannover.bgr.de/grsn.html>

GRF  
 STS-1 seismometer  
 source: [http://www.iris.washington.edu/FDSN/GR/GRF/station\\\_insr.html](http://www.iris.washington.edu/FDSN/GR/GRF/station\_insr.html)  
 there are exact calibration and gains at this www site  
 as average value for the calibration 1.22 can be used  
 error: max 10%  
 inverse gain: 3.310937e-11

The files T\_V\_\*.FLF listed below are filter files for the Seismic Handler (SH) programme by K. Stammler (Graefenberg), see:

<http://www.szgrf.uni-erlangen.de/softarchive.html>

The filter files are designed for the frequency domain, e.g. usage in SH:

file f T\_V\_\*

Note: No additional calibration values should be used, because average calibration values are contained in the gain of the filter files.

As output the "true" velocity in nm/s should be given. The instrument response of the seismometers is corrected with the calculated poles and zeros.

The gain is corrected by using the inverse of the gain and the generator constant.

To compute the displacement (the T\_D\_\*.FLF files) one just add a pole (0.0,0.0) to the poles in the T\_V\_\*.FLF file.

Comment lines start with an exclamation sign "!". The first line after the comments is a control number 1357913578. This identifies the file to be an SH filter file. The next line is another ID number, specifying the filter type. For FFT filter files this is 1. The next line contains a normalization constant which is multiplied to the filtered trace, unit is nano meter per sec. per count [nm/s/count]. Next line gives the number of zeroes of the filter. The following lines are pairs of the complex conjugated zeroes. Next line gives the number of poles of the filter. And the following lines are pairs of the complex conjugated poles.

```
! T_V_GREF3T.FLF
! velocity Guralp T3 at Reftek (nm/s)
! GFZ Potsdam
! source: handbook T3 (To=100s, d=0.707)
!
! gain: average gain 1.262 - 1.284
! used APPROXIMATION: 1.273
! error < 2!
1357913578
1
1.273
2
(-4.442212E-02,4.44355E-02)
(-4.442212E-02,-4.44355E-02)
2
(0.0,0.0)
(0.0,0.0)

! T_V_GREF40T.FLF
! velocity Guralp 40T and Reftek (nm/s)
! GFZ Potsdam
! source: handbook 40T (To=30s, d=0.707)
!
! gain: average gain 2.371 - 2.394
! used APPROXIMATION: 2.3825
! error < 2!
1357913578
1
2.3825
2
(-0.1480737,0.14811846)
(-0.1480737,-0.14811846)
2
(0.0,0.0)
```

(0.0,0.0)

! T\_V\_GREFSTS2  
! velocity STS-2 and Reftek (nm/s)  
! GFZ Potsdam  
! STS-2 manual

!

! average gain: 1.271

! error < 2!

1357913578

1

1.271

2

(-3.7018433E-02,-3.7029614E-02)

(-3.7018433E-02,3.7029614E-02)

2

(0.0,0.0)

(0.0,0.0)

! T\_V\_GREFMARK.FLF  
! velocity MARK L4 at Reftek (nm/s)  
! GFZ Potsdam  
! source: Bribach GFZ and APPROXIMATION !

!

! To 1 s

! gain: average gain: 9.85 - 12.73 (max. range)

! mostly: 10.0

! used approximation: 11.16

! max error: 10! (for REFTEK gain setting 1)

!

1357913578

1

11.61

2

(-4.5E+00,4.5E+00)

(-4.5E+00,-4.5E+00)

2

(0.0000000000000000E+00,0.0000000000000000E+00)

(0.0000000000000000E+00,0.0000000000000000E+00)

! T\_V\_BPDASMARK.FLF  
! velocity PDAS and MARK (nm/s)  
! Bochum stations  
! MARK L4 3D at PDAS  
! source: Bribach GFZ and APPROXIMATION !

!

! the approximation should be valid within +/- 5!

1357913578

1

2.9E-03

2  
 (-4.6E+00,4.6E+00)  
 (-4.6E+00,-4.6E+00)  
 2  
 (0.000000000000000E+00,0.000000000000000E+00)  
 (0.000000000000000E+00,0.000000000000000E+00)

! T\_V\_MARSLE1.FLF  
 ! velocity LE-3D 1s at MARS88 (nm/s)  
 ! Zuerich station  
 ! source: R.Arlitt (To=1s, d=0.707)  
 !  
 ! 1 count = 1 uV  
 ! generator constant = 400 Vs/m  
 !

1357913578  
 1  
 2.5  
 2  
 (-4.442212E-00,4.44355E-00)  
 (-4.442212E-00,-4.44355E-00)  
 2  
 (0.0,0.0)  
 (0.0,0.0)

! T\_V\_POLMARK1.FLF  
 ! velocity MARK 1s at Polish recorder (nm/s)  
 ! source: S.Hock and M.Zuchniak  
 !  
 ! (To=1s, d=0.7)  
 ! gain from generator constant and LSB of digitizer  
 !

1357913578  
 1  
 3.9745786e-16  
 10  
 (-580.282e00,-225.202e00)  
 (-580.282e00,225.202e00)  
 (-141.028e00,-30.734e00)  
 (-141.028e00,30.734e00)  
 (-102.722e00,191.632e00)  
 (-102.722e00,-191.632e00)  
 (-0.421884e00,-0.239338e00)  
 (-0.421884e00,0.239338e00)  
 (-4.4429e00,4.4429e00)  
 (-4.4429e00,-4.4429e00)  
 4  
 (0.0,0.0)  
 (0.0,0.0)  
 (0.0,0.0)

(0.0,0.0)

! T\_V\_POLMARK2.FLF  
! velocity MARK 0.5s at Polish recorder (nm/s)  
! source: S.Hock and M.Zuchniak (To=0.5s, d=0.7)

!  
! gain manually adjusted  
! only major 2 poles used

!  
1357913578

1  
6.15e-02  
2  
(-8.531968e00,-8.704349e00)  
(-8.531968e00,8.704349e00)

2  
(0.0,0.0)  
(0.0,0.0)

! T\_V\_SORIMARK2.FLF  
! velocity MARK 0.5s at Swedish Orion recorder (nm/s)  
! source: S.Hock (To=0.5s, d=0.7)

!  
! gain from generator constant and LSB of digitizer  
! gain = 271.6 / 203.3 count/nm/s = 1.3360 count/nm/s

!  
1357913578

1  
0.7485  
2  
(-8.79645943E+00,8.97418363E+00)  
(-8.79645943E+00,-8.97418363E+00)

2  
(0.0,0.0)  
(0.0,0.0)

! T\_V\_SORILE1.FLF  
! velocity Lennartz LE3D 1s at Swedish Orion recorder (nm/s)  
! source: S.Hock (To=1s, d=0.7)

!  
! gain from generator constant and LSB of digitizer  
! gain = 400.0 / 203.3 count/nm/s = 1.9675 count/nm/s

!  
1357913578

1  
0.50825  
2  
(-4.39822971E+00,4.48709182E+00)  
(-4.39822971E+00,-4.48709182E+00)

2

(0.0,0.0)  
 (0.0,0.0)

! T\_V\_SORILE5.FLF  
 ! velocity Lennartz LE3D 5s at Swedish Orion recorder (nm/s)  
 ! source: S.Hock (To=5s, d=0.7)  
 !  
 ! gain from generator constant and LSB of digitizer  
 ! gain = 400.0 / 203.3 count/nm/s = 1.9675 count/nm/s  
 !  
 1357913578  
 1  
 0.50825  
 2  
 (-0.879645943E+00,0.897418363E+00)  
 (-0.879645943E+00,-0.897418363E+00)  
 2  
 (0.0,0.0)  
 (0.0,0.0)

! T\_V\_LREFESP.FLF  
 ! velocity Guralp ESP and Reftek (nm/s)  
 ! Uni Leipzig  
 ! (To=30s, d=0.707)  
 !  
 ! gain: 1 at Reftek 1.907 uV per LSB  
 ! average generator constant used  
 ! error < 3!  
 1357913578  
 1  
 0.9527  
 2  
 (-0.1480737,0.14811846)  
 (-0.1480737,-0.14811846)  
 2  
 (0.0,0.0)  
 (0.0,0.0)

! T\_V\_GRSN.FLF  
 ! velocity German Regional Seismic Network (nm/s)  
 ! = inverse STS-2 transfer functions  
 ! source SZGRF and GFZ Potsdam  
 !  
 ! with average calibration included (1.67)  
 !  
 1357913578  
 1  
 1.67  
 2  
 (-3.7003625E-02,-3.7014801E-02)



```
(-3.7003625E-02,3.7014801E-02)
2
(0.0,0.0)
(0.0,0.0)

! T_V_GRF.FLF
! velocity Graefenberg (nm/s)
! inverse STS-1
! source: http://www.iris.washington.edu/FDSN/GR/GRF/station\_insr.html
!
! average calibration value: 1.22
! error: max 10! gain: 3.310937e-11
! the gain below includes the average calibration value !!
!
1357913578
1
4.03934e-11
9
(-0.2221,0.2221)
(-0.2221,-0.2221)
(-31.4159,0.)
(-7.0058,30.6248)
(-7.0058,-30.6248)
(-19.5721,24.5742)
(-19.5721,-24.5742)
(-28.3058,13.6288)
(-28.3058,-13.6288)
2
(0.0,0.0)
(0.0,0.0)
```