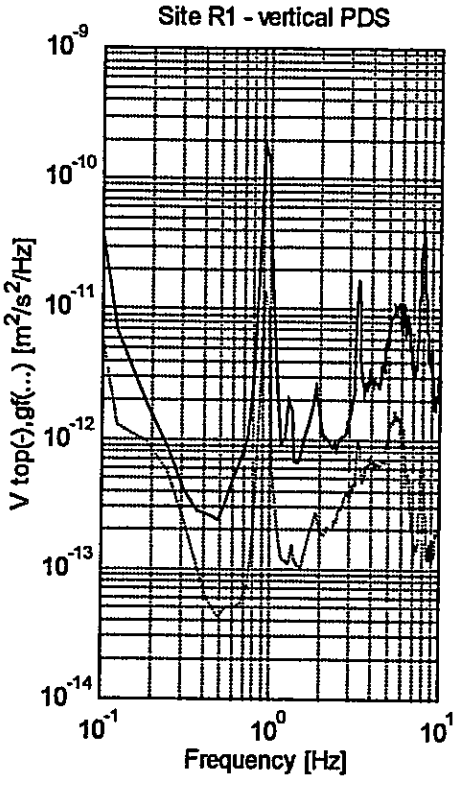
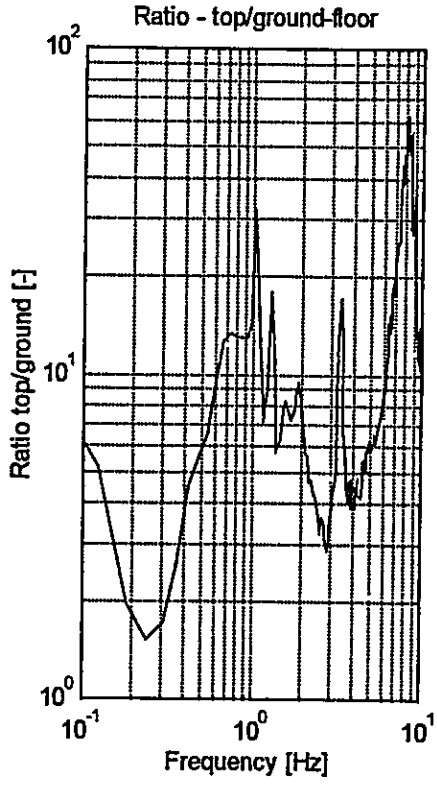
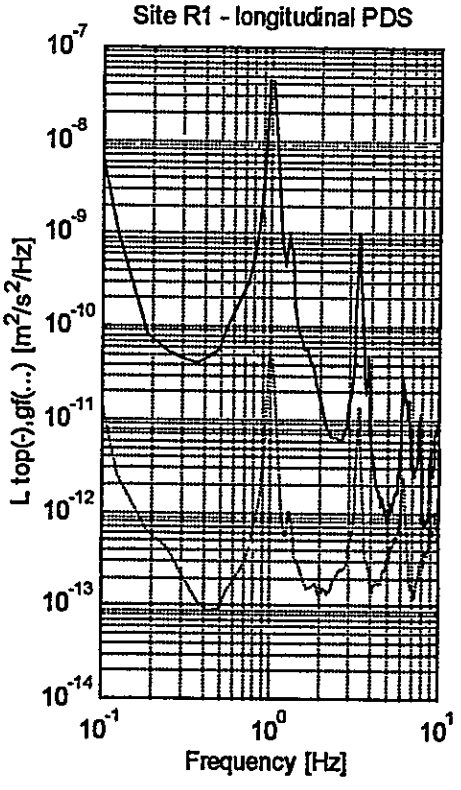
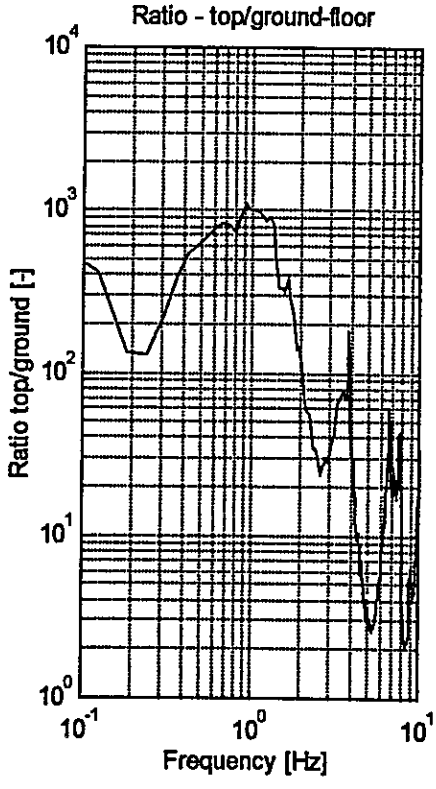
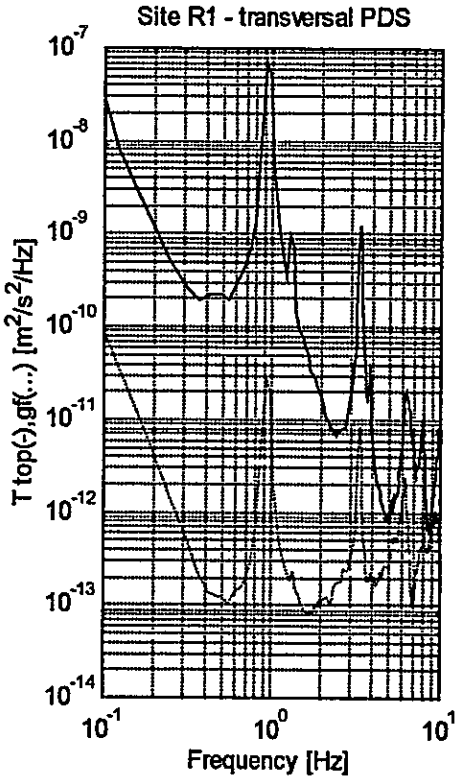
5.3.x Site R1 - Spectral data, spectral ratio, and particle motion

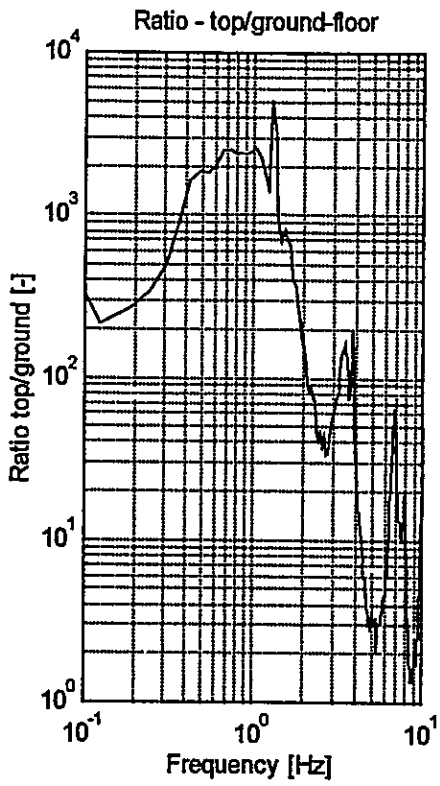


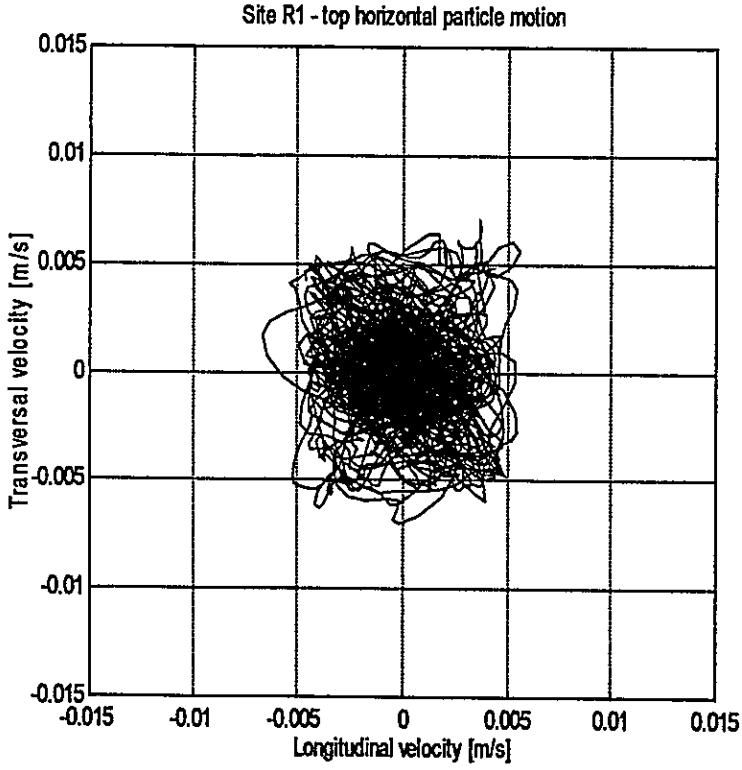




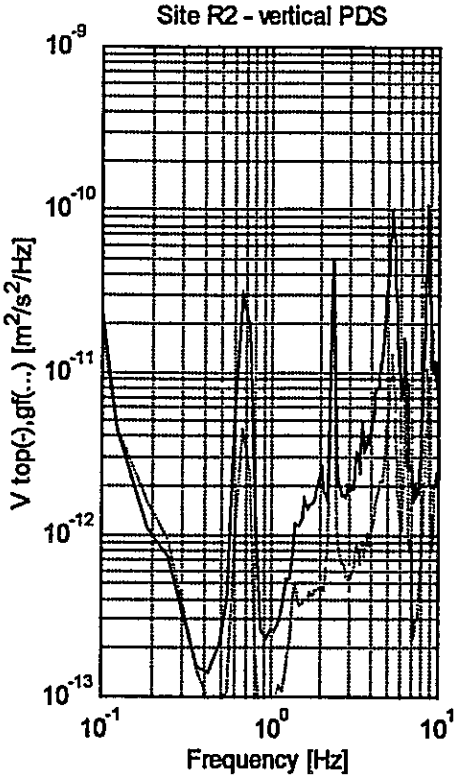


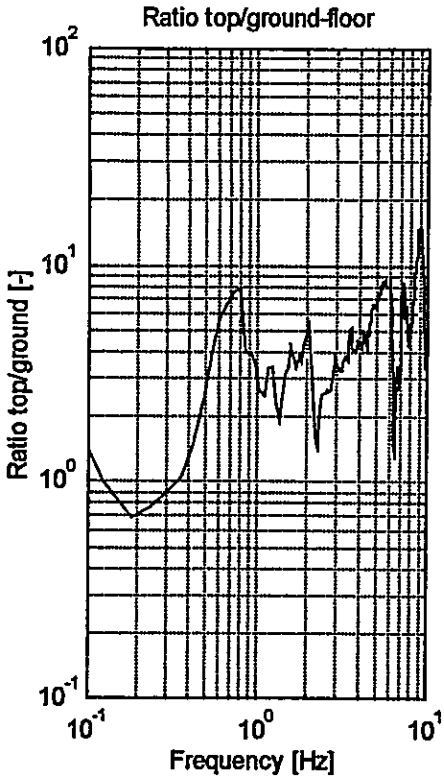

Site R1 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

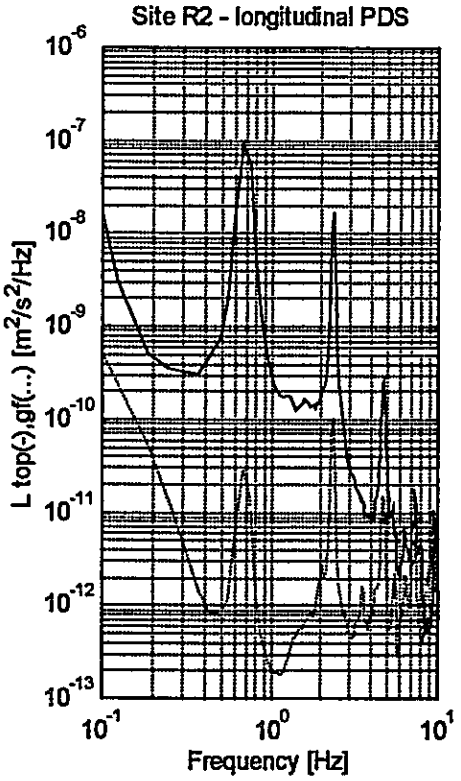

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

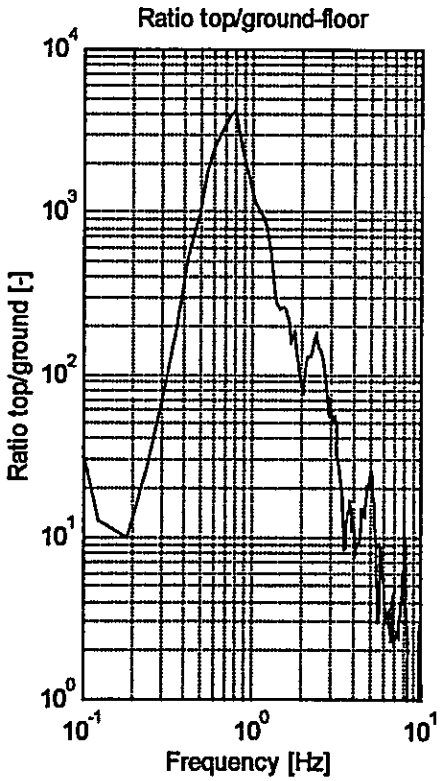

Site R1 - top horizontal particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

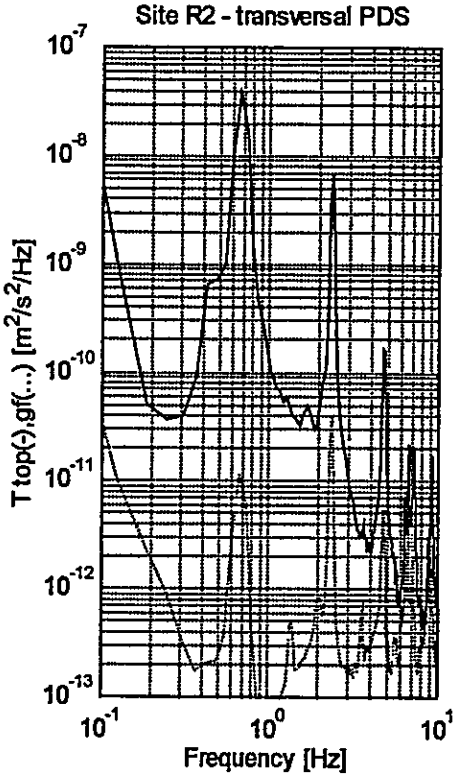
5.3.x Site R2 - Spectral data, spectral ratio, and particle motion

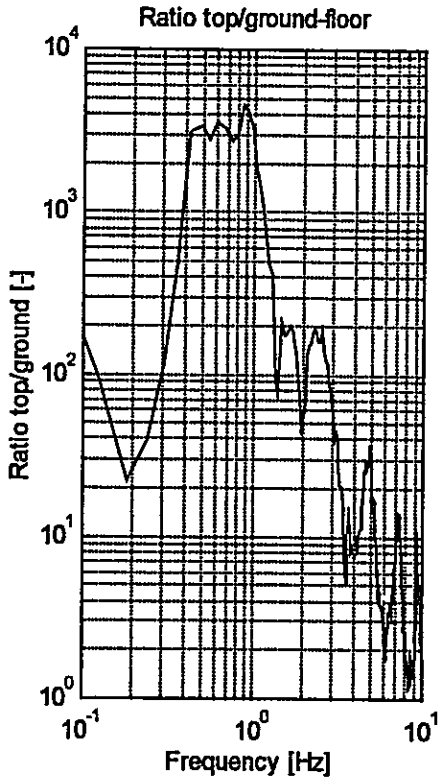


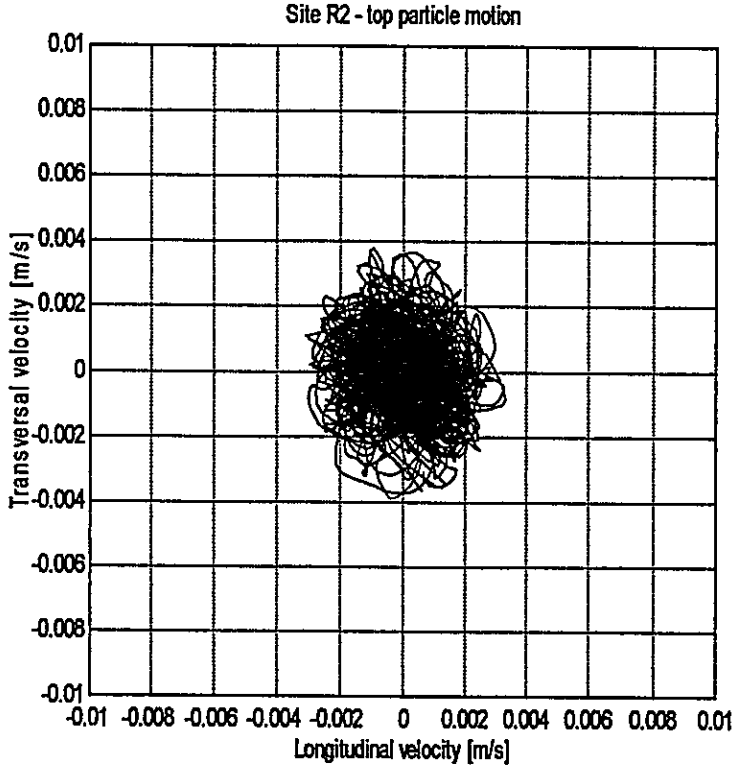




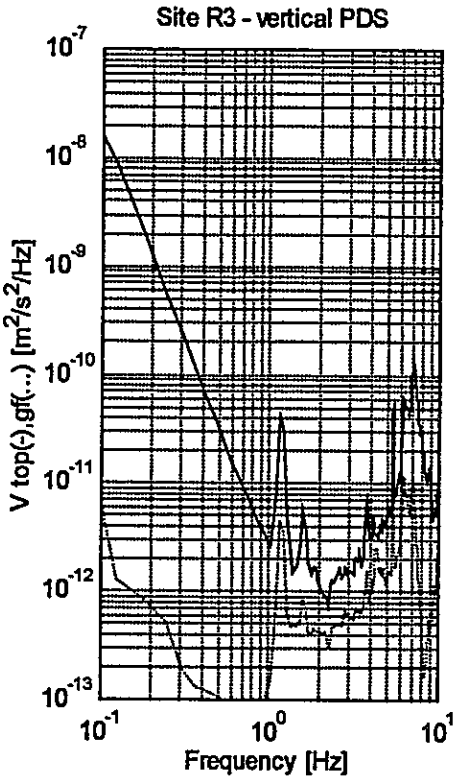


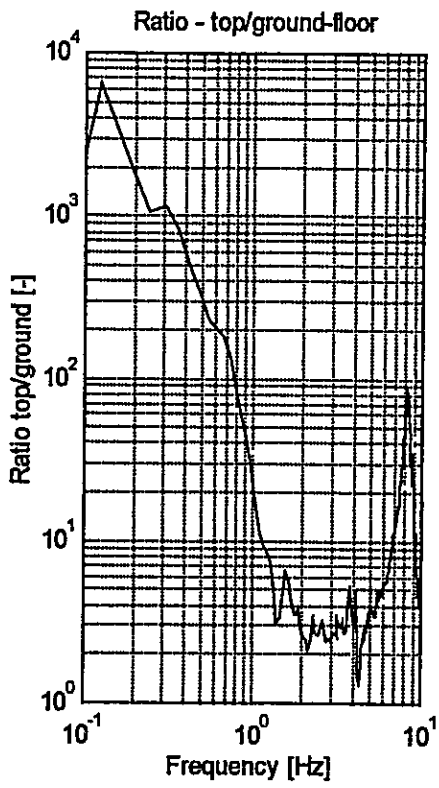

Site R2 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

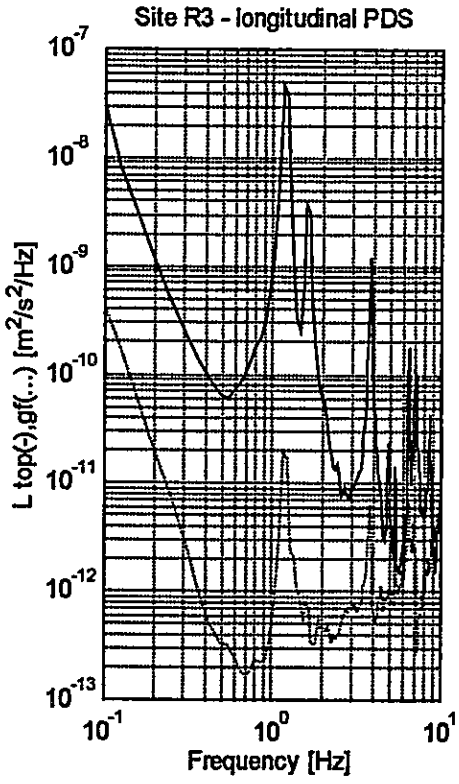

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

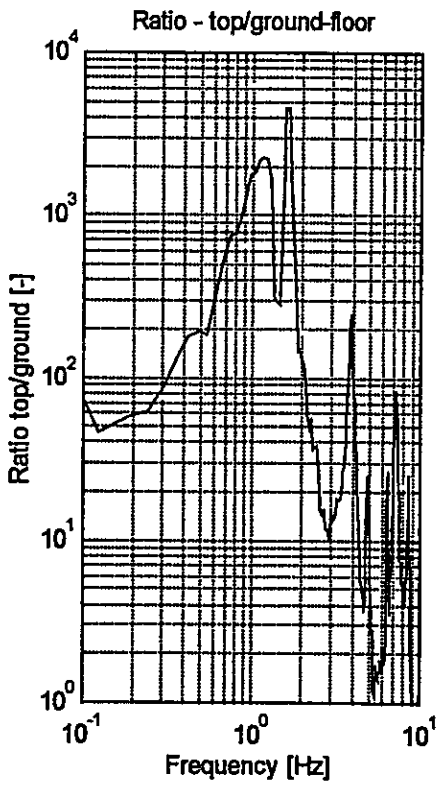

Site R2 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

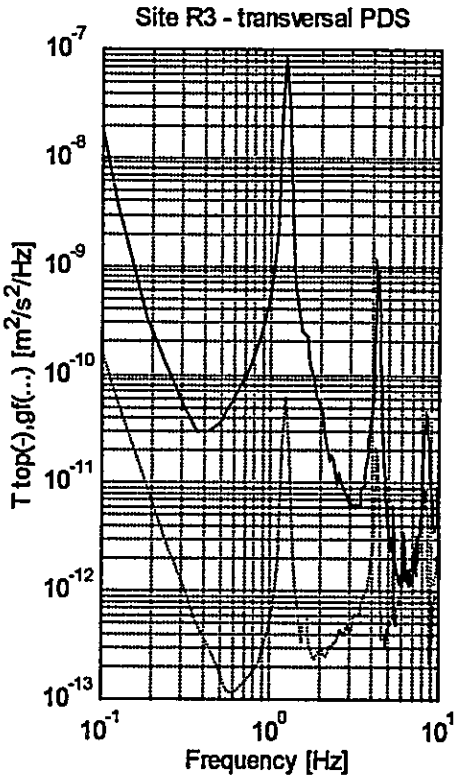
5.3.x Site R3 - Spectral data, spectral ratio, and particle motion.

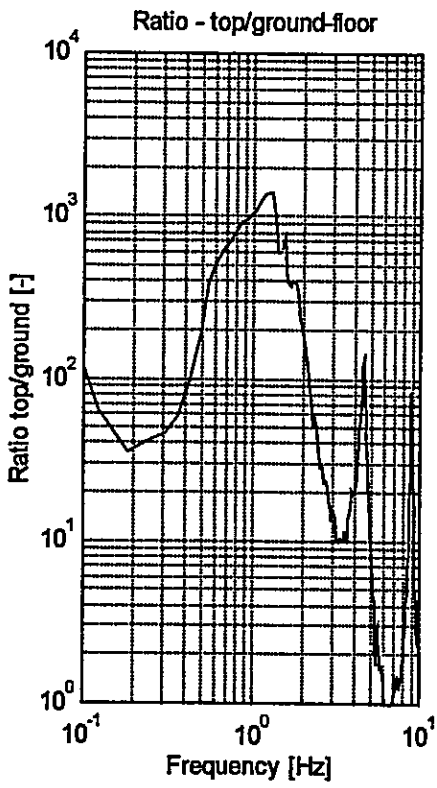


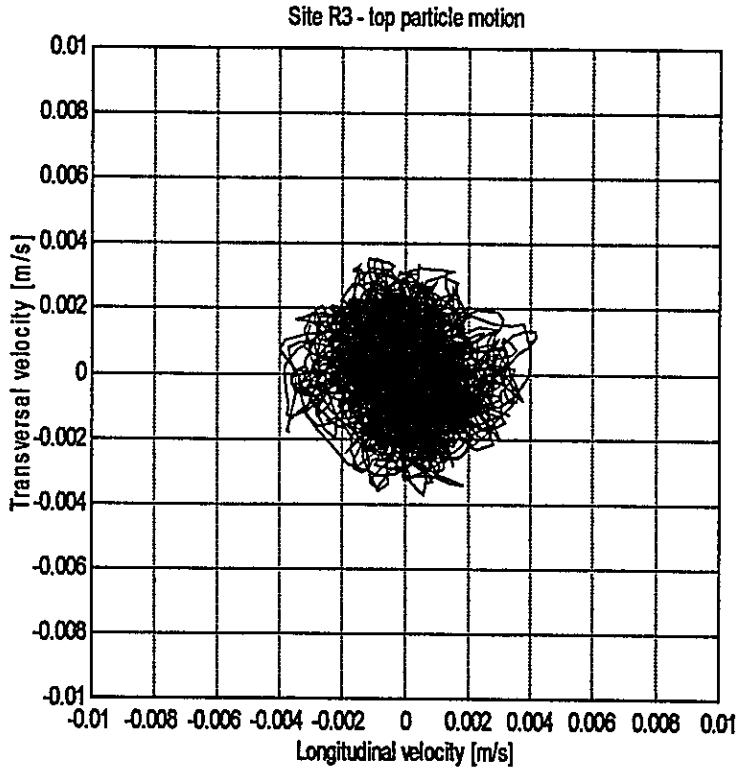




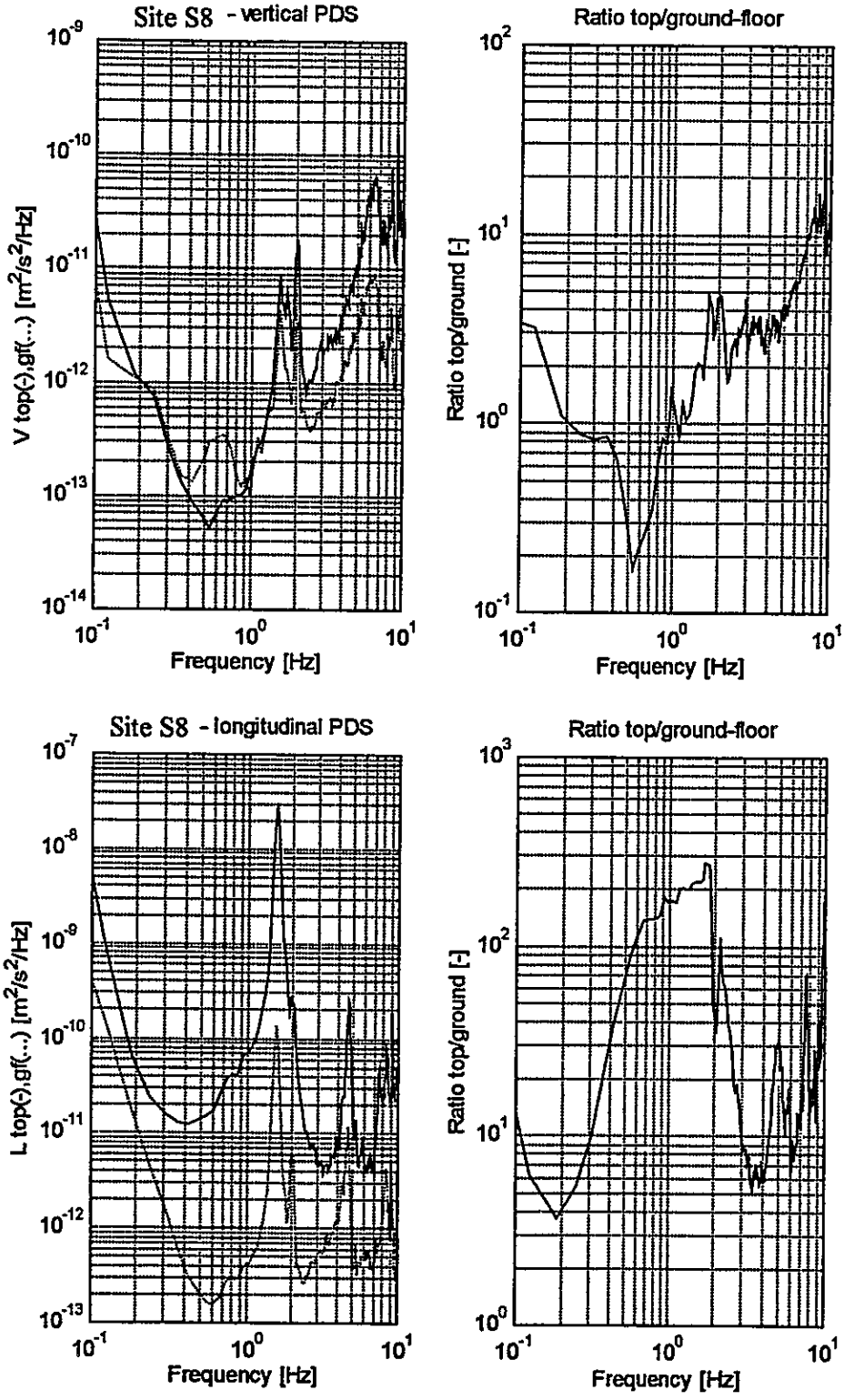


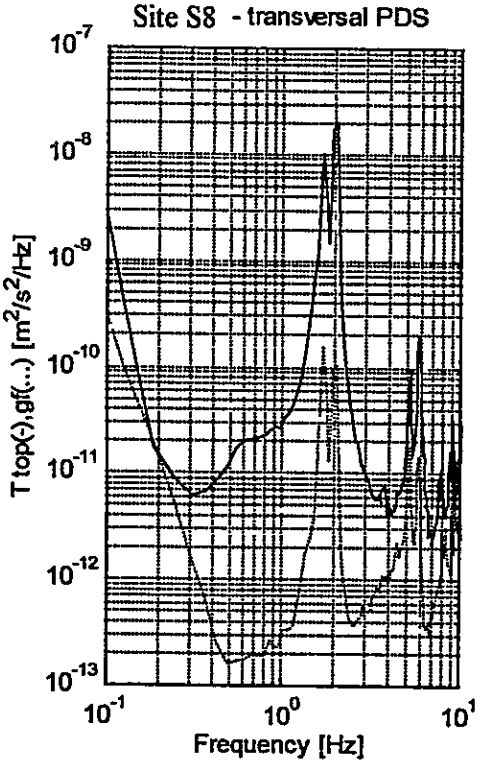

Site R3 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

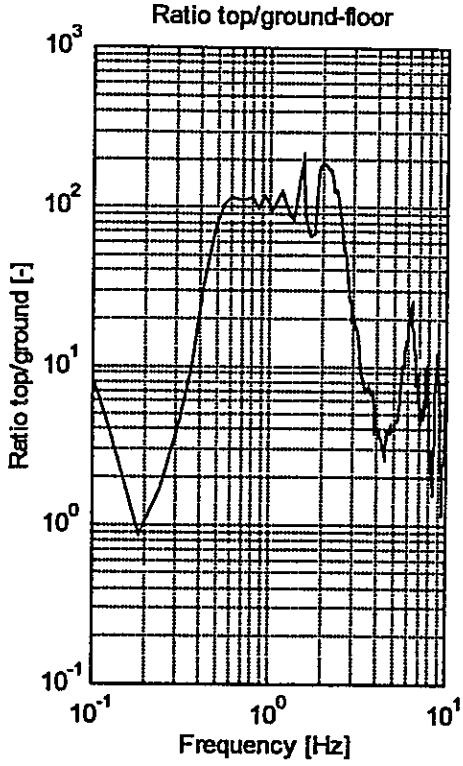

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

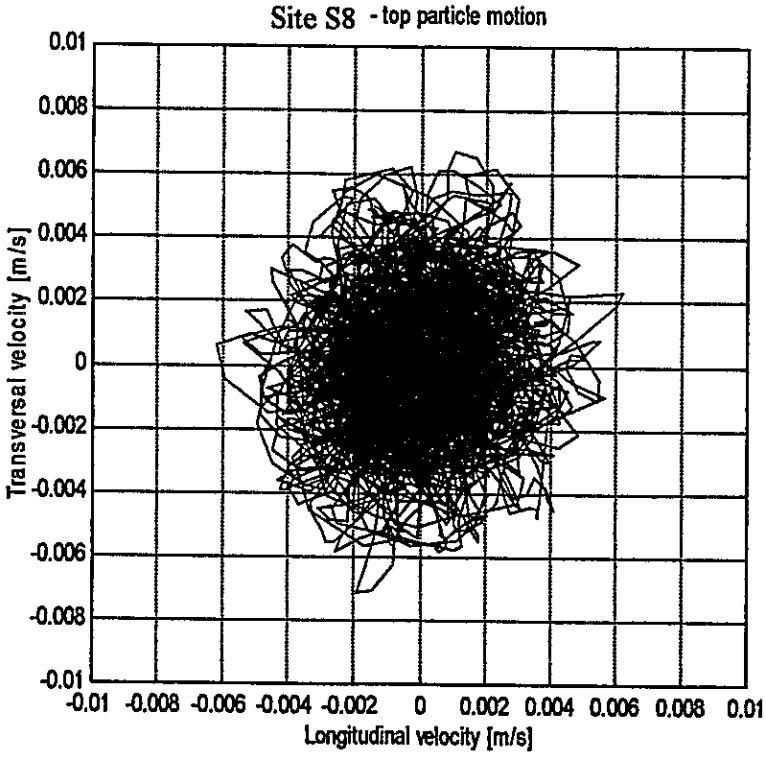

Site R3 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

5.3.x Site S8 - Spectral data, spectral ratio, and particle motion.

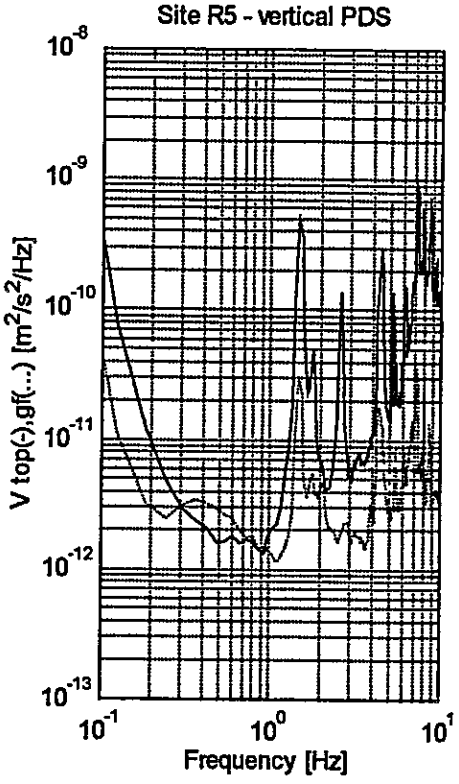


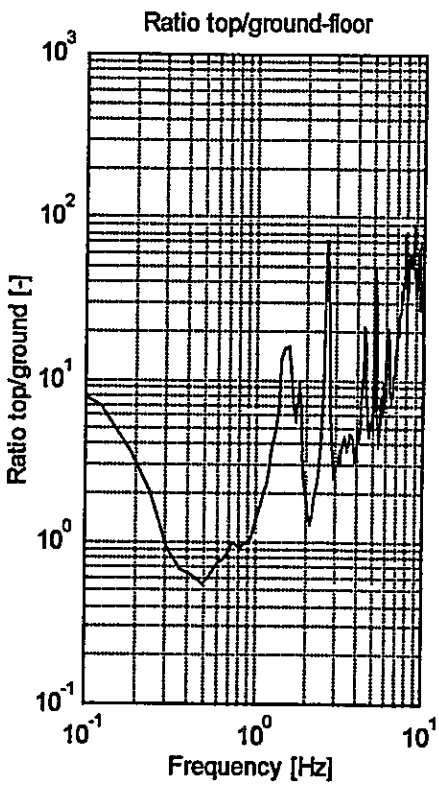

Site S8 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

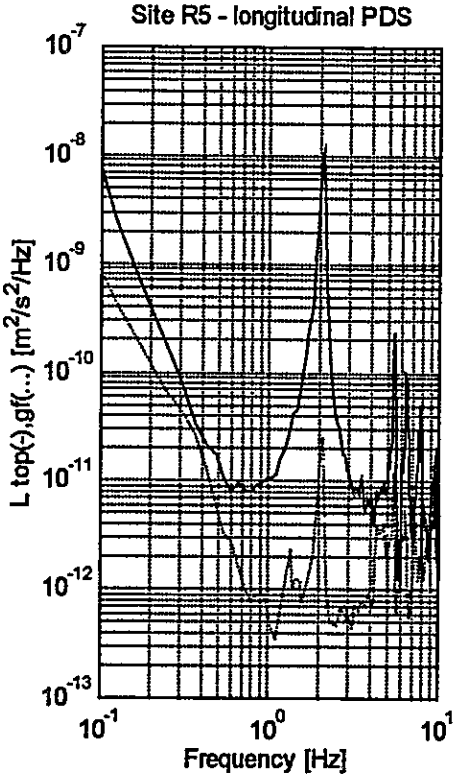

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

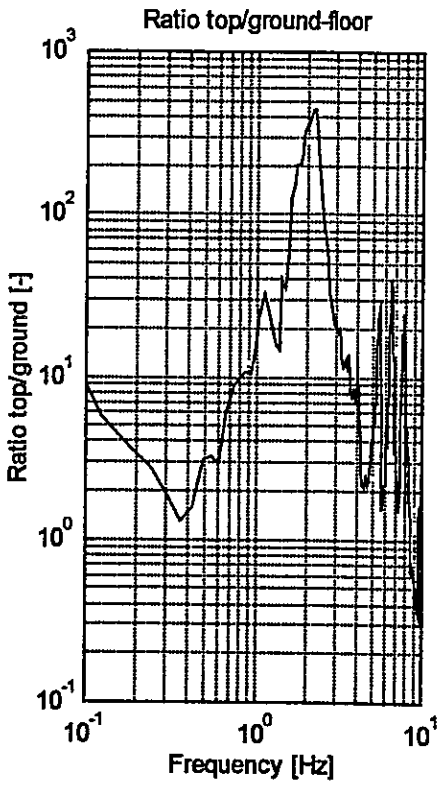

Site S8 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

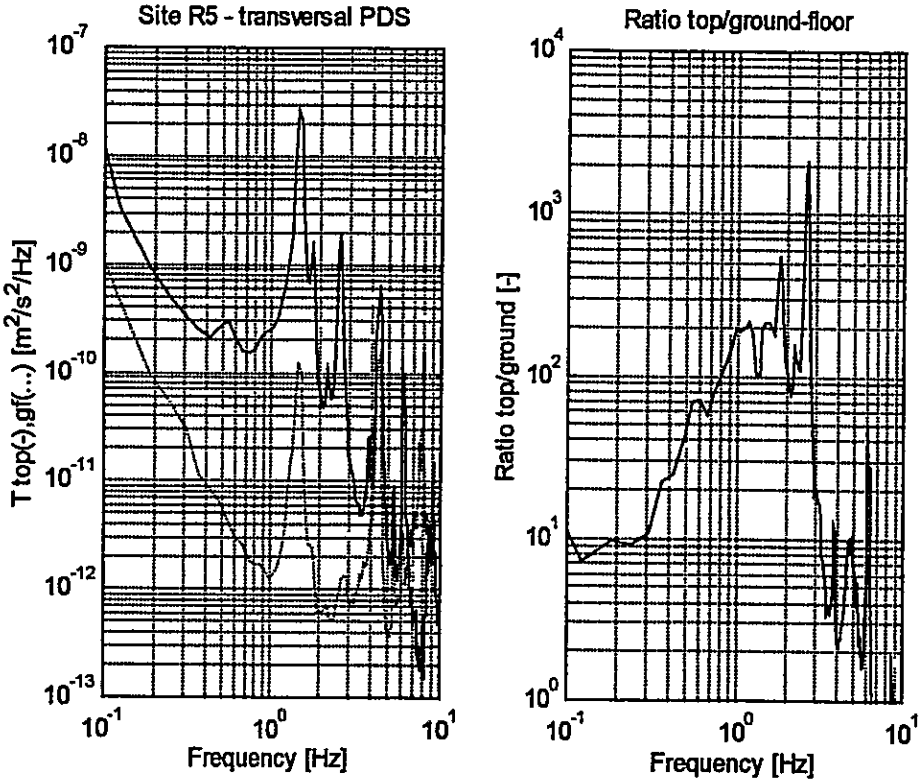
5.3.x Site R5 - Spectral data, spectral ratio, and particle motion.

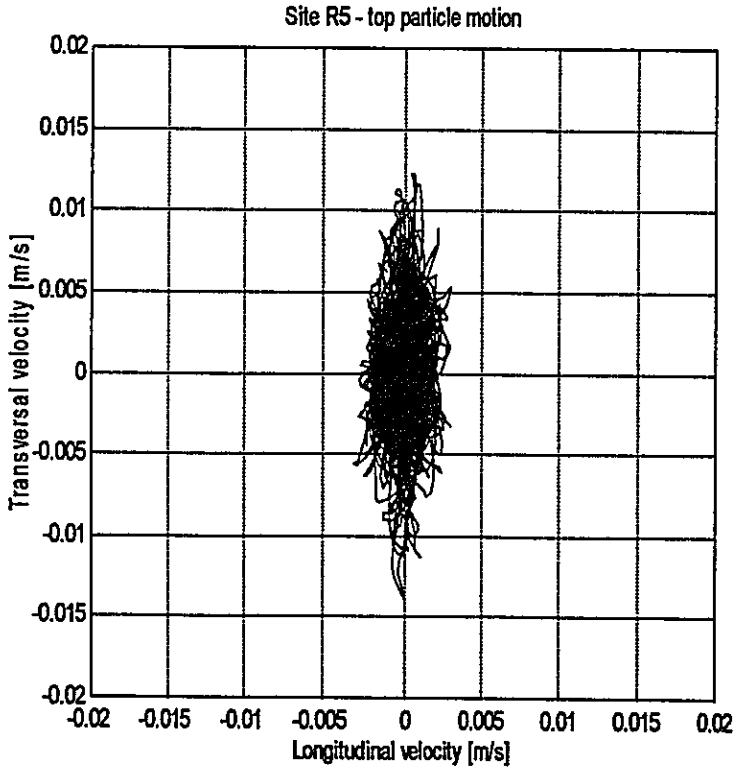




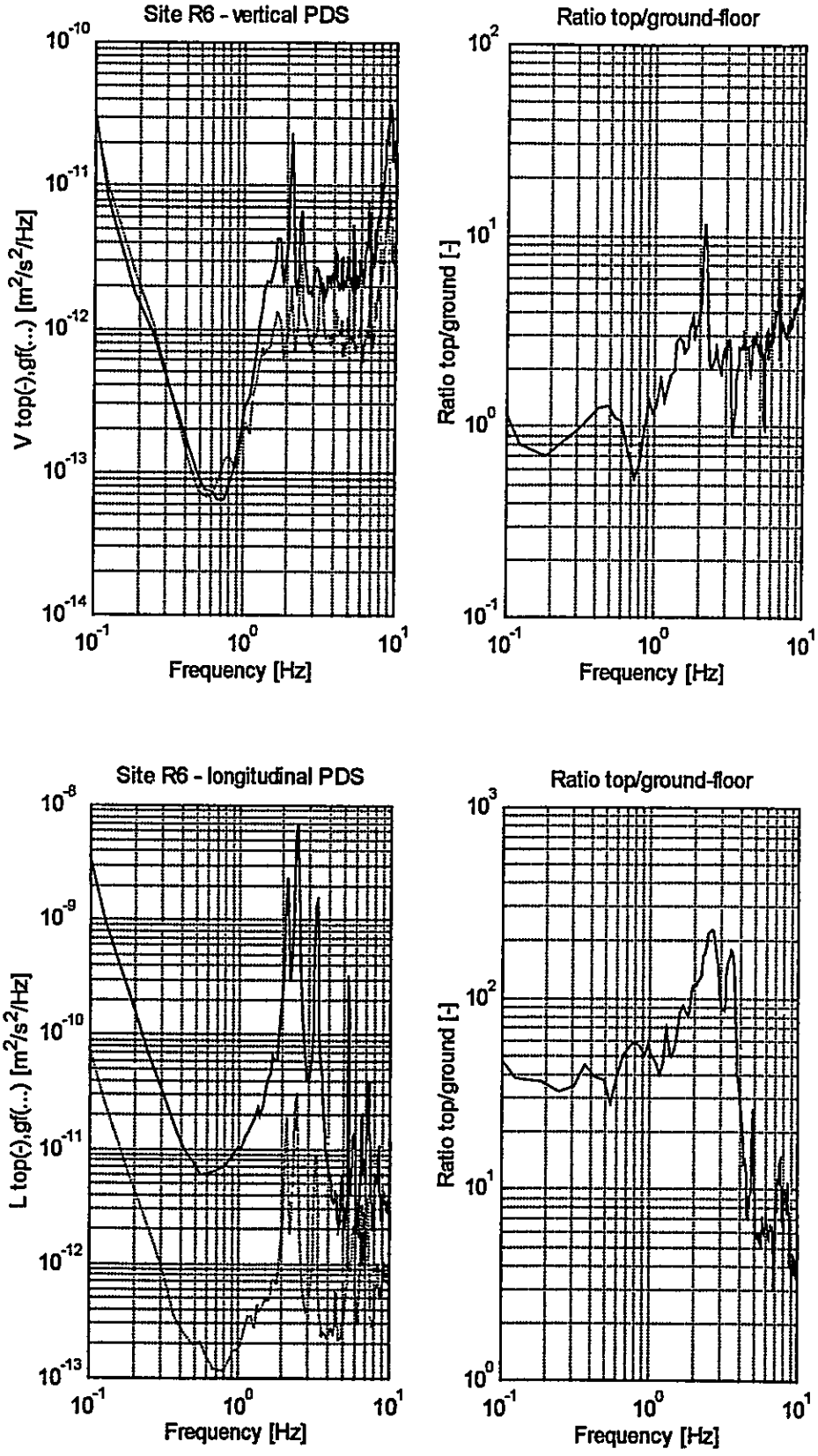


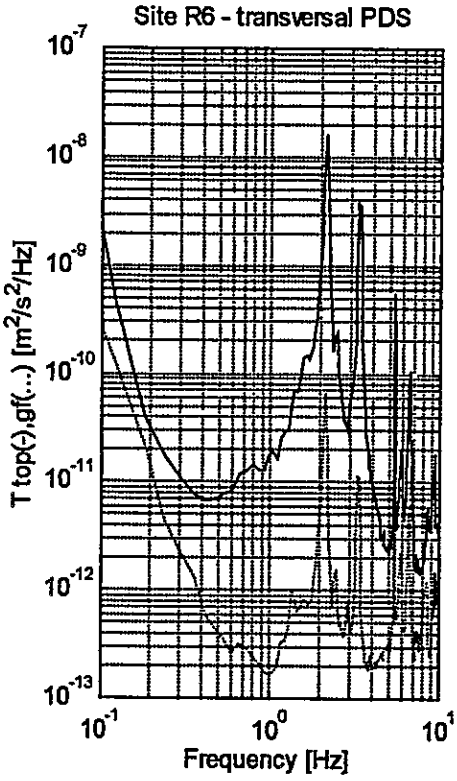


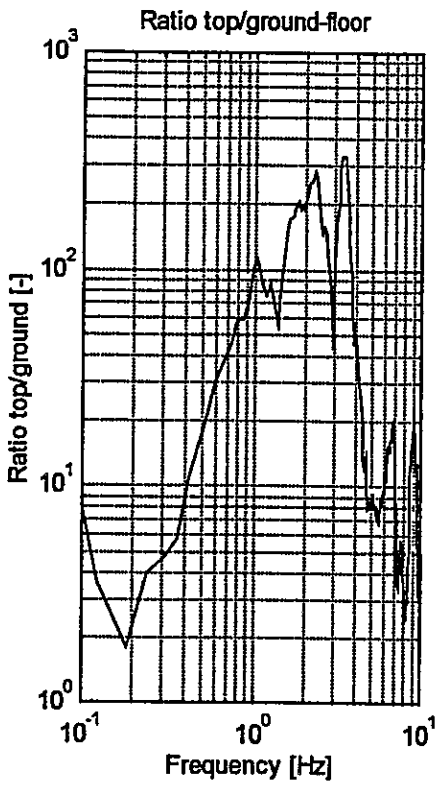

Site R5 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

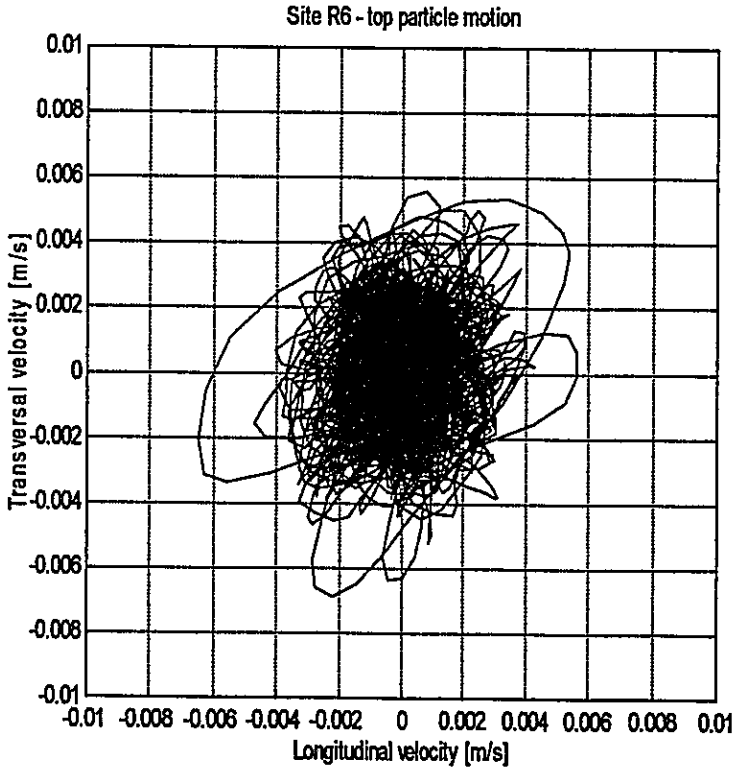

Site R5 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

5.3.x Site R6 - Spectral data, spectral ratio, and particle motion

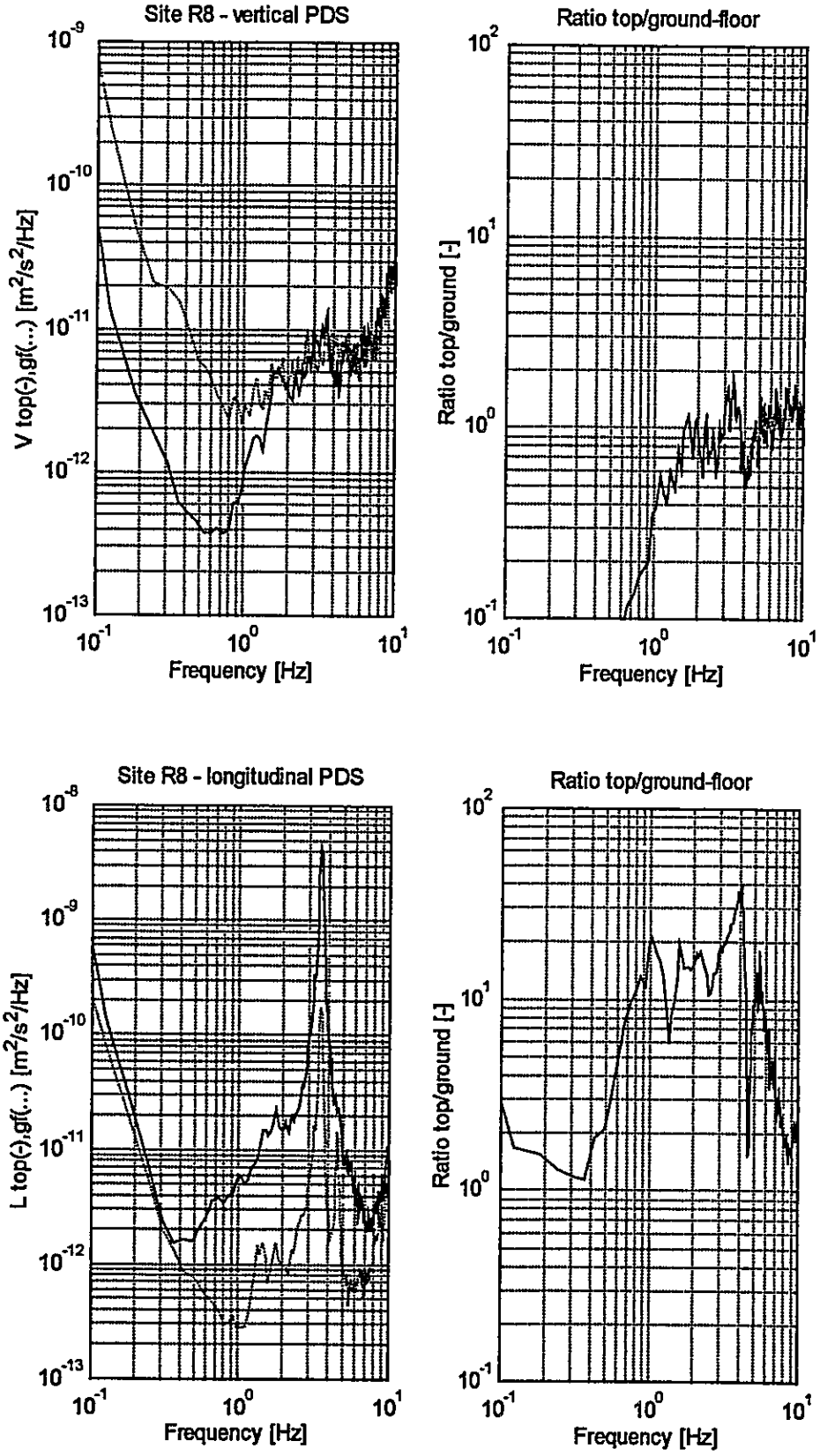


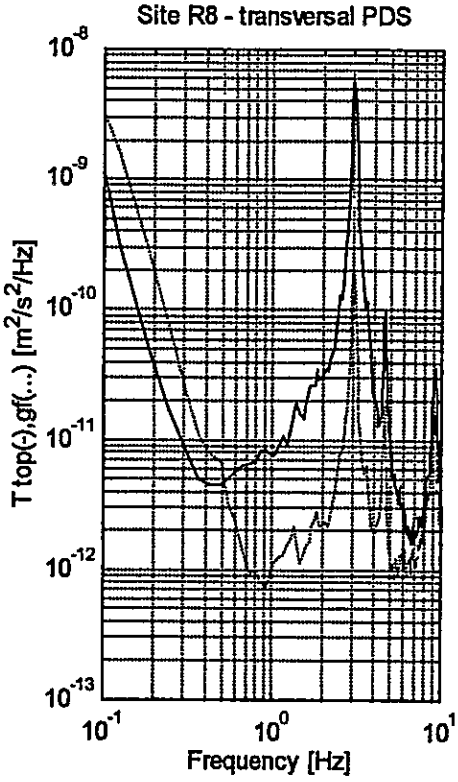

Site R6 - transversal PDS
T top(-),gf(...) [m²/s⁴/Hz]
Frequency [Hz]

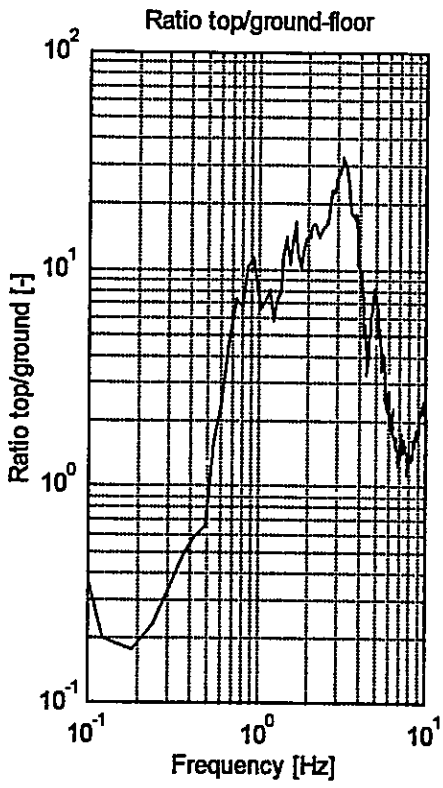

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

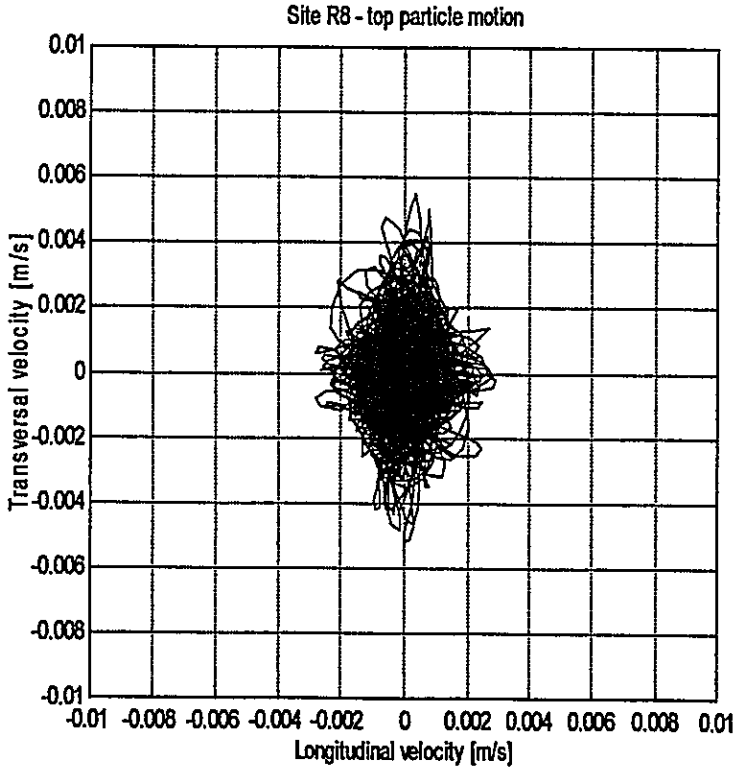

Site R6 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

5.3.x Site R8 - Spectral data, spectral ratio, and particle motion

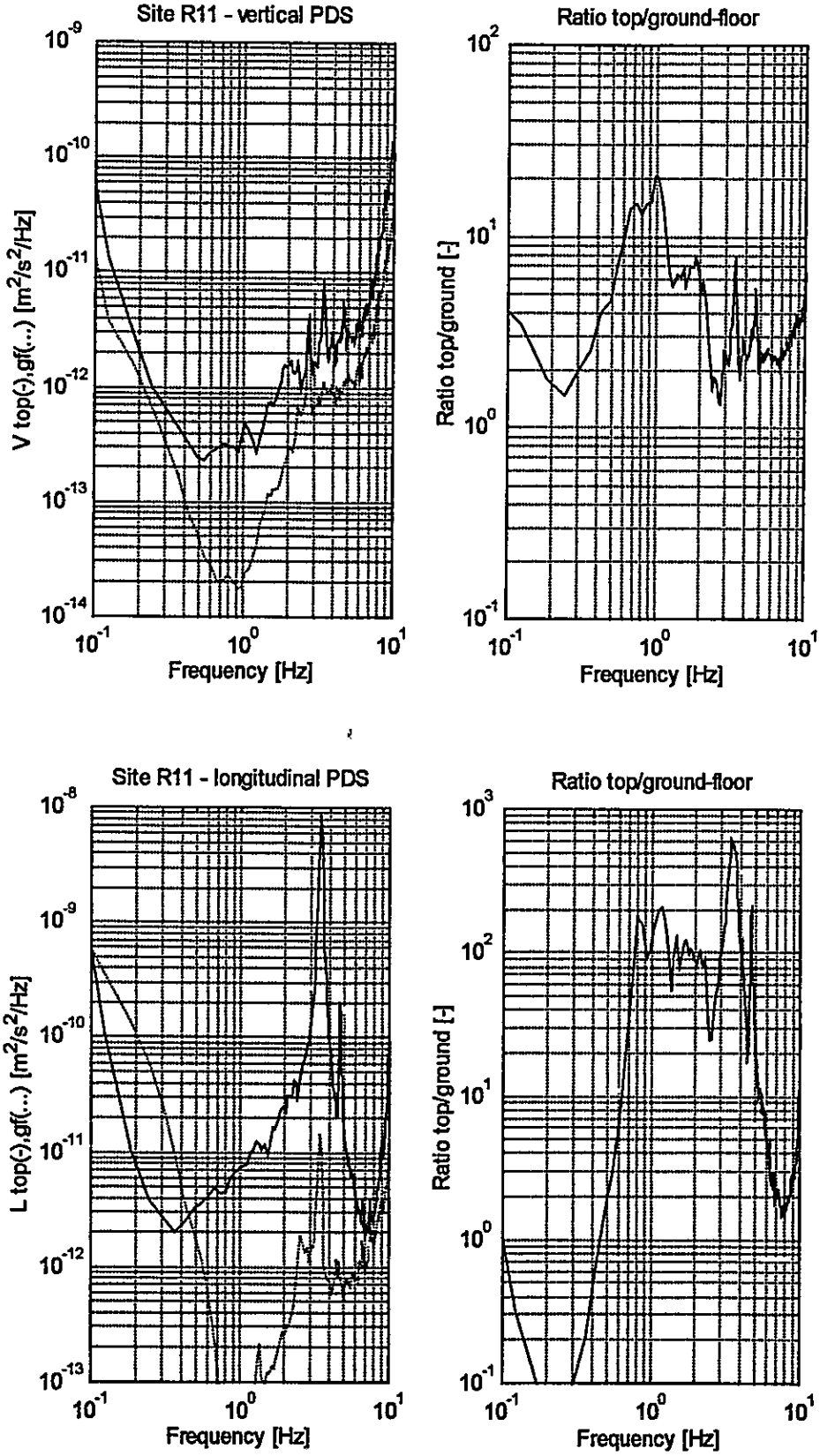


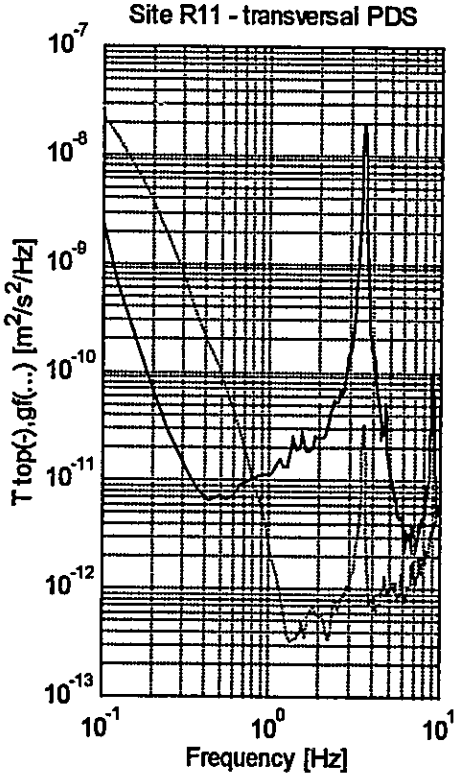

Site R8 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

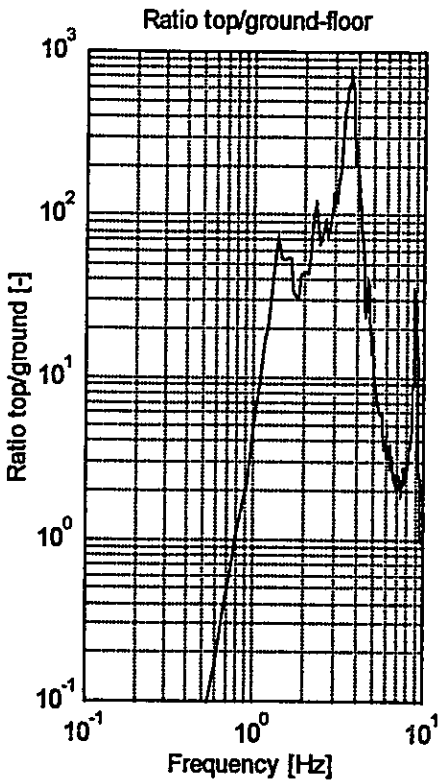

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

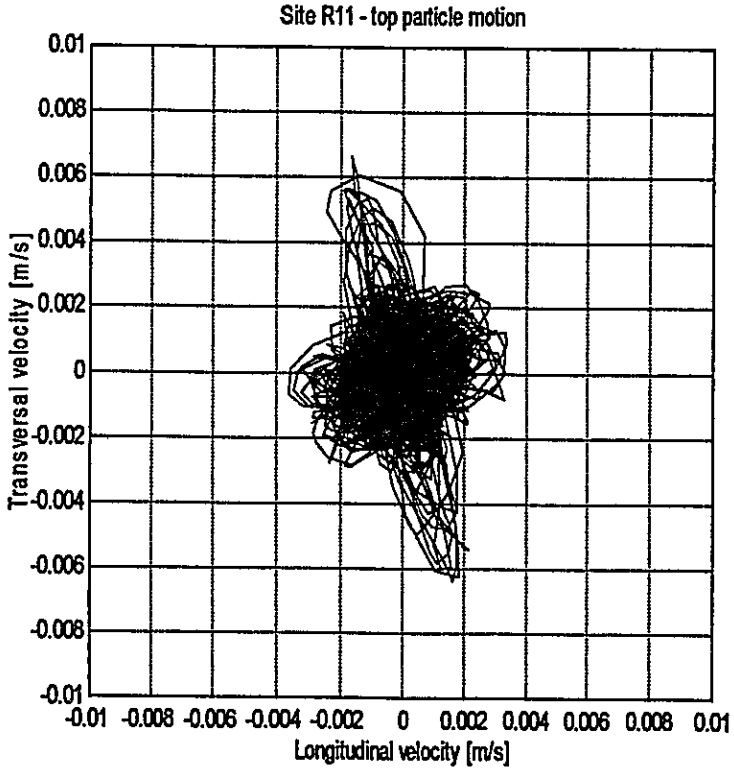

Site R8 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

5.3.x Site R11 - Spectral data, spectral ratio, and particle motion

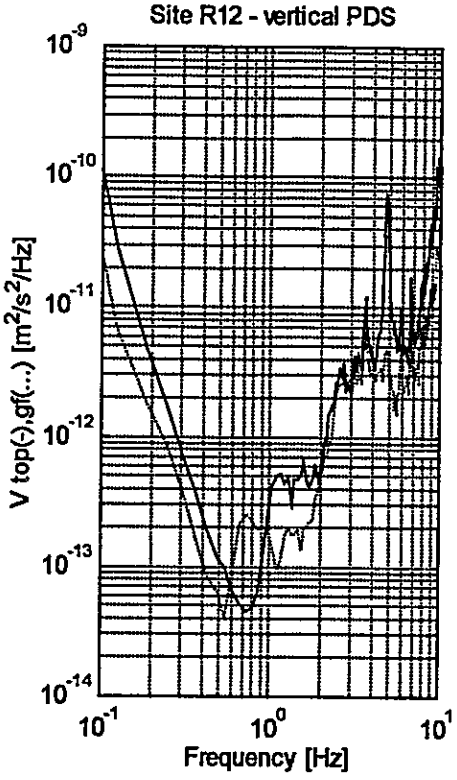


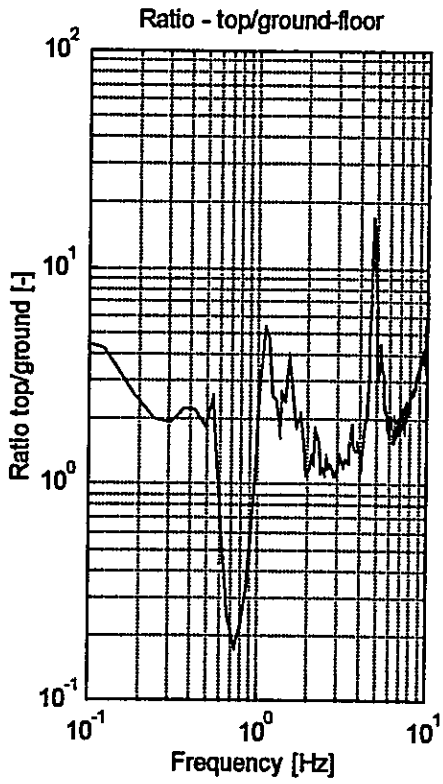

Site R11 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

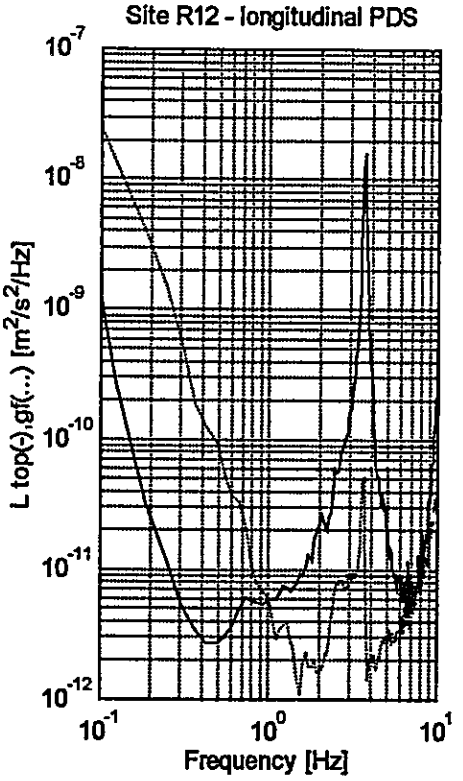

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

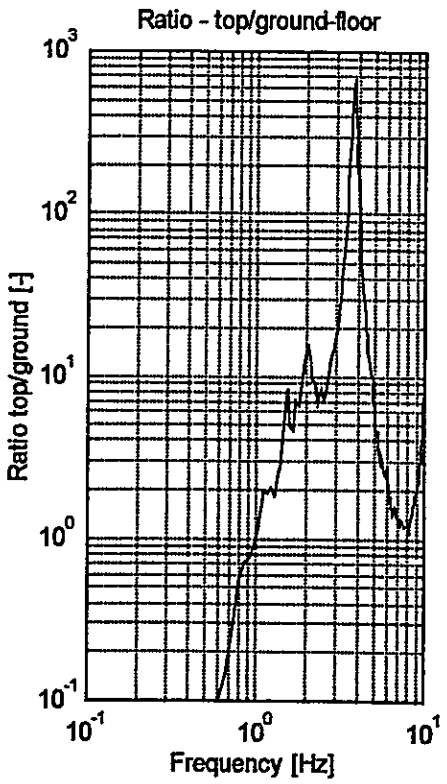

Site R11 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

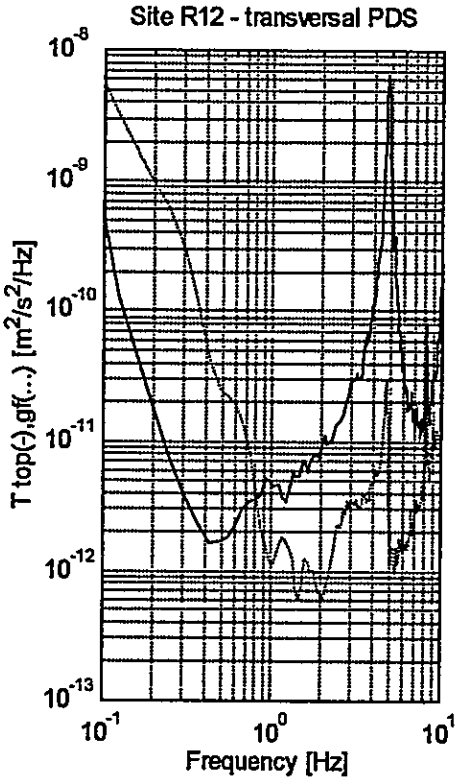
5.3.x Site R12 - Spectral data, spectral ratio, and particle motion.

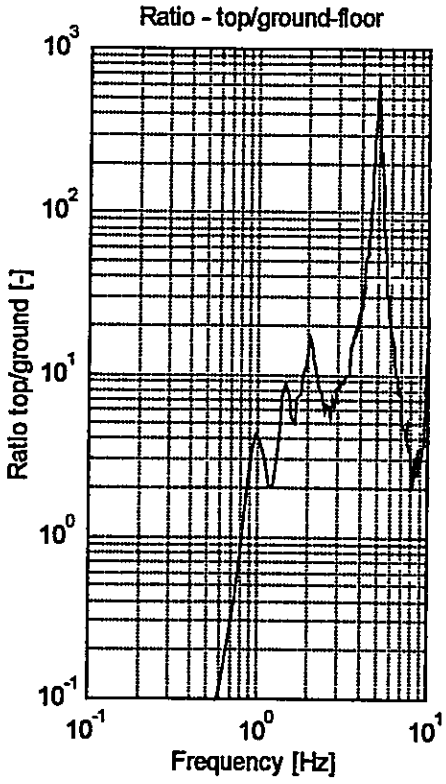


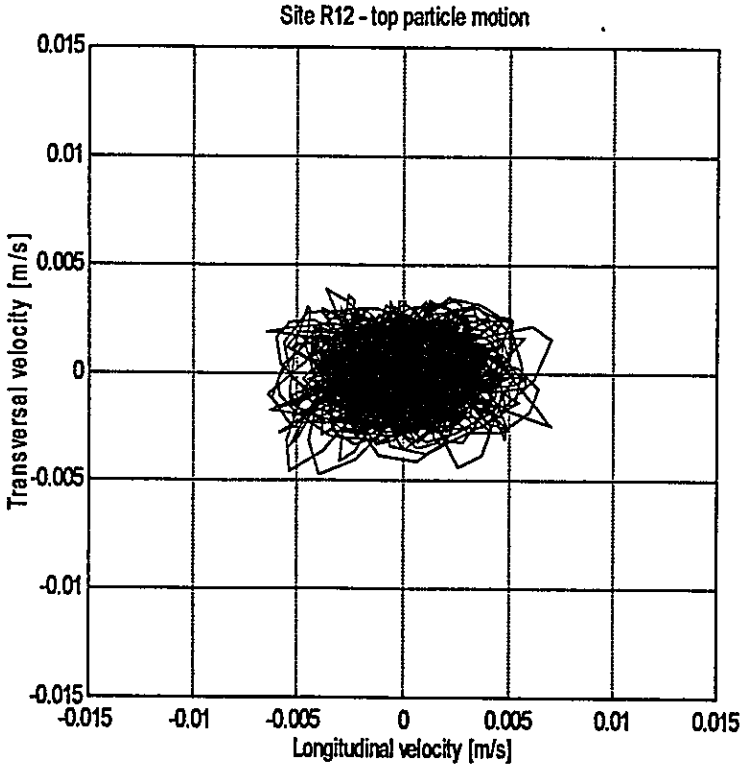




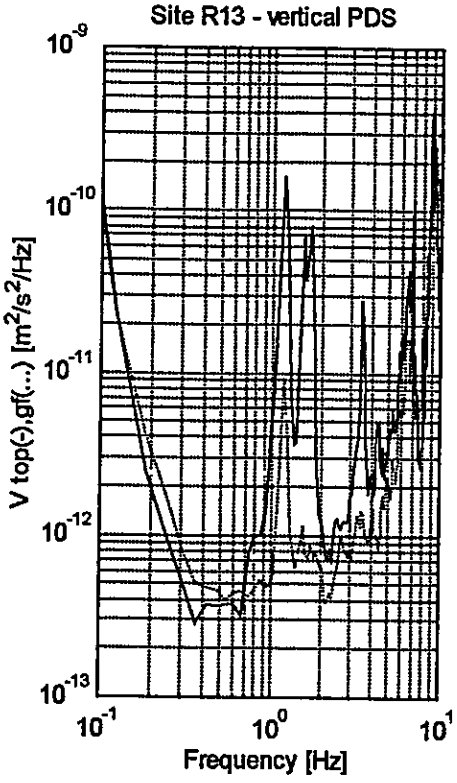


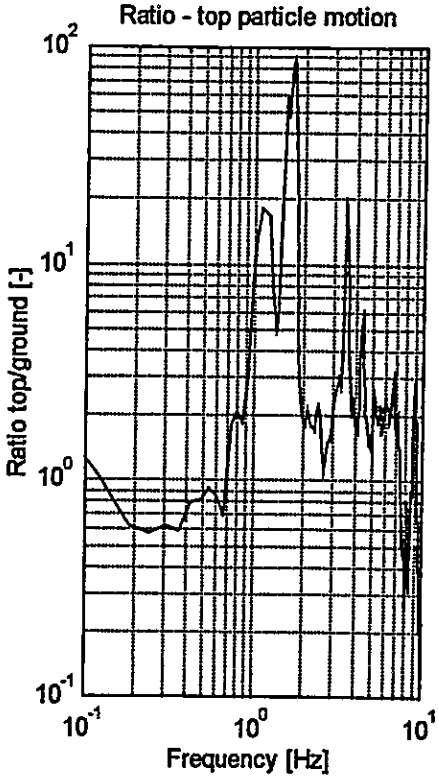

Site R12 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

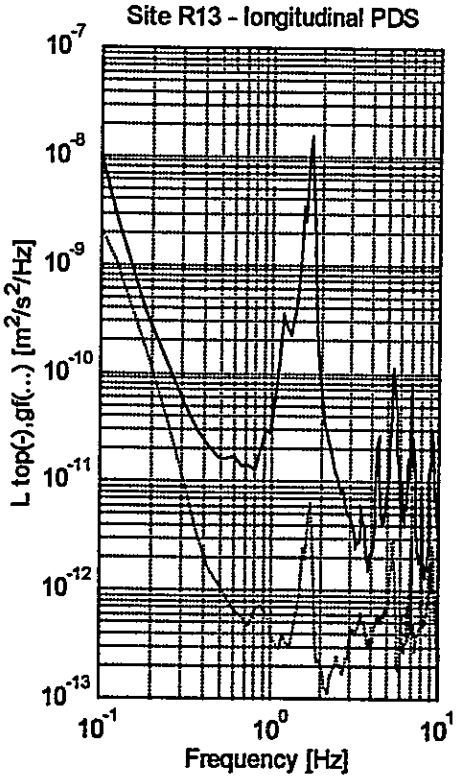

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

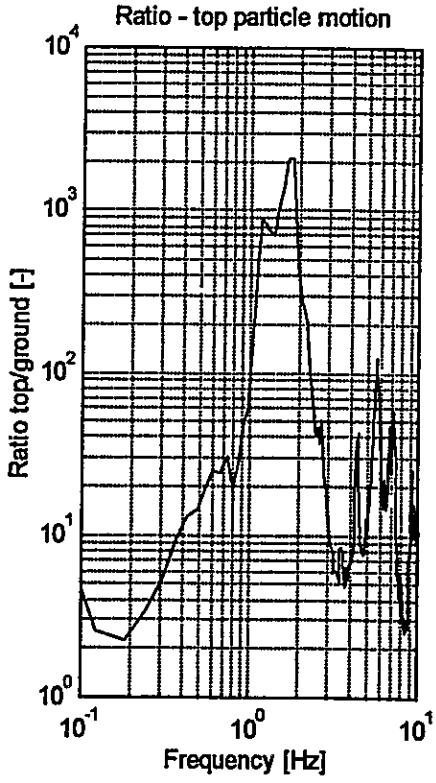

Site R12 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

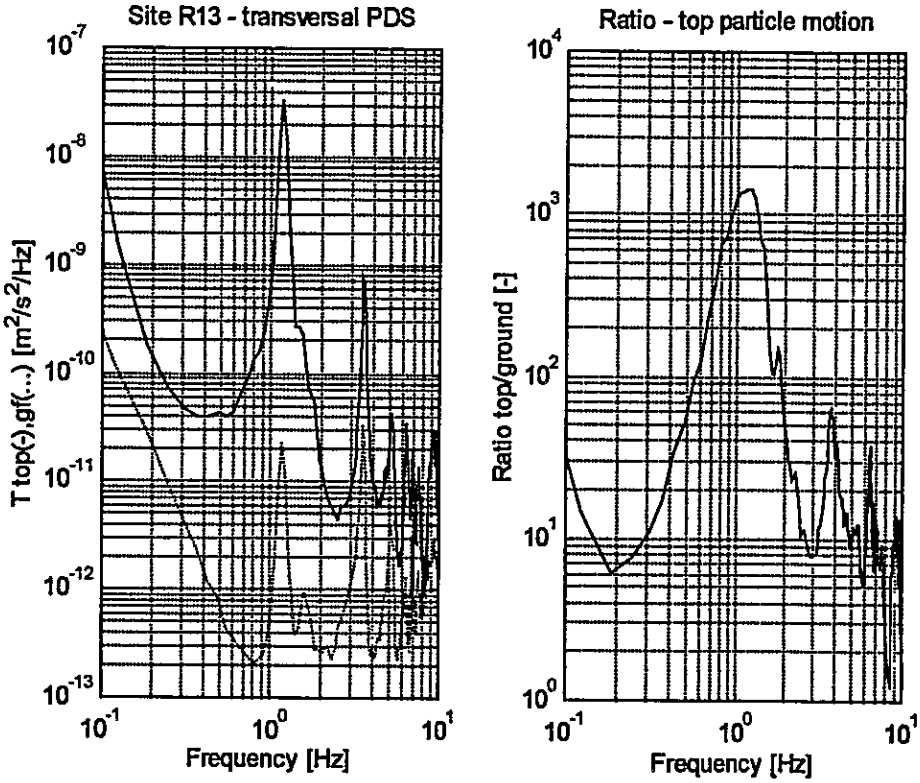
5.3.x Site R13 - Spectral data, spectral ratio, and particle motion.

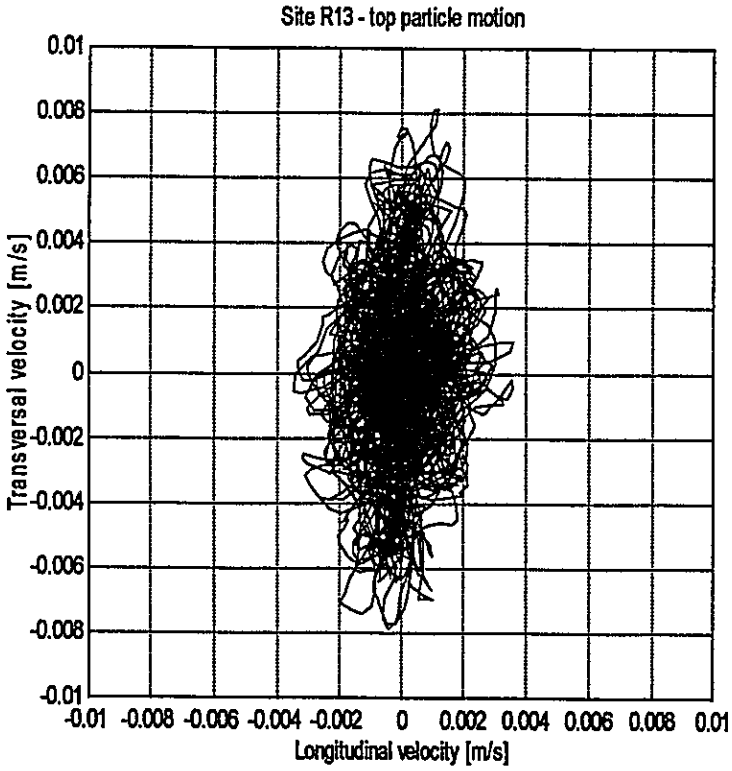




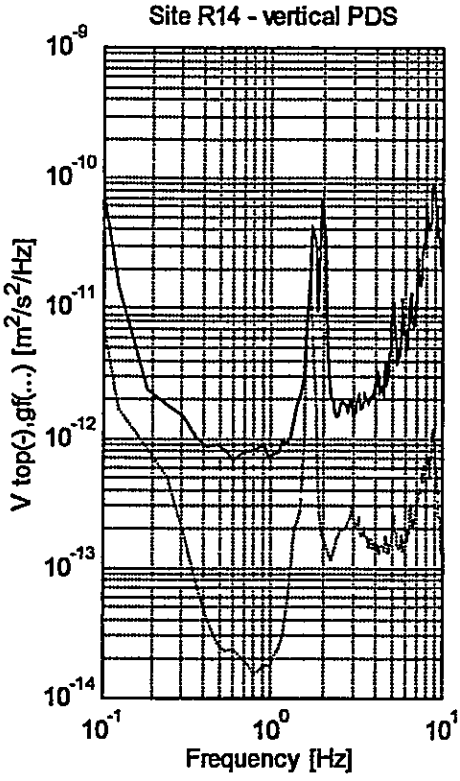


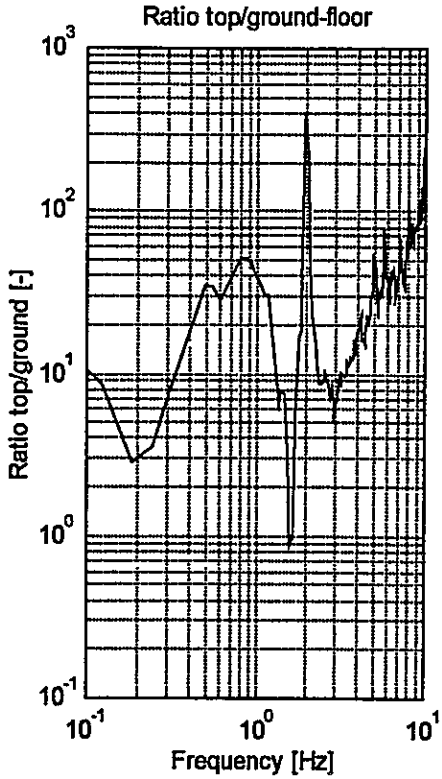


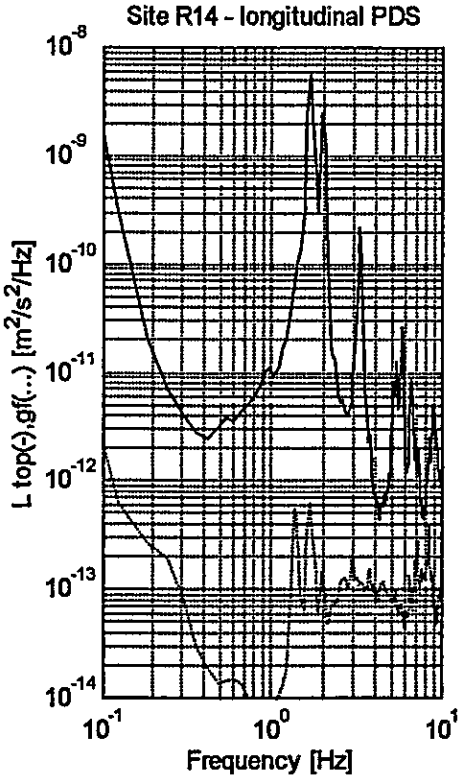

Site R13 - transversal PDS
T top(·),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio - top particle motion
Ratio top/ground [-]
Frequency [Hz]

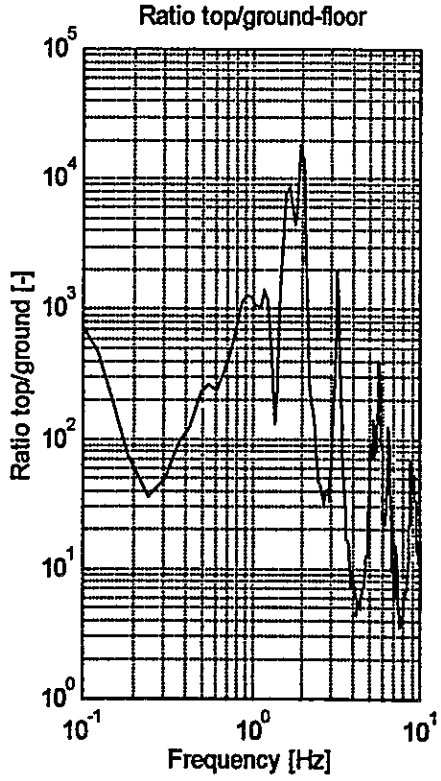

Site R13 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

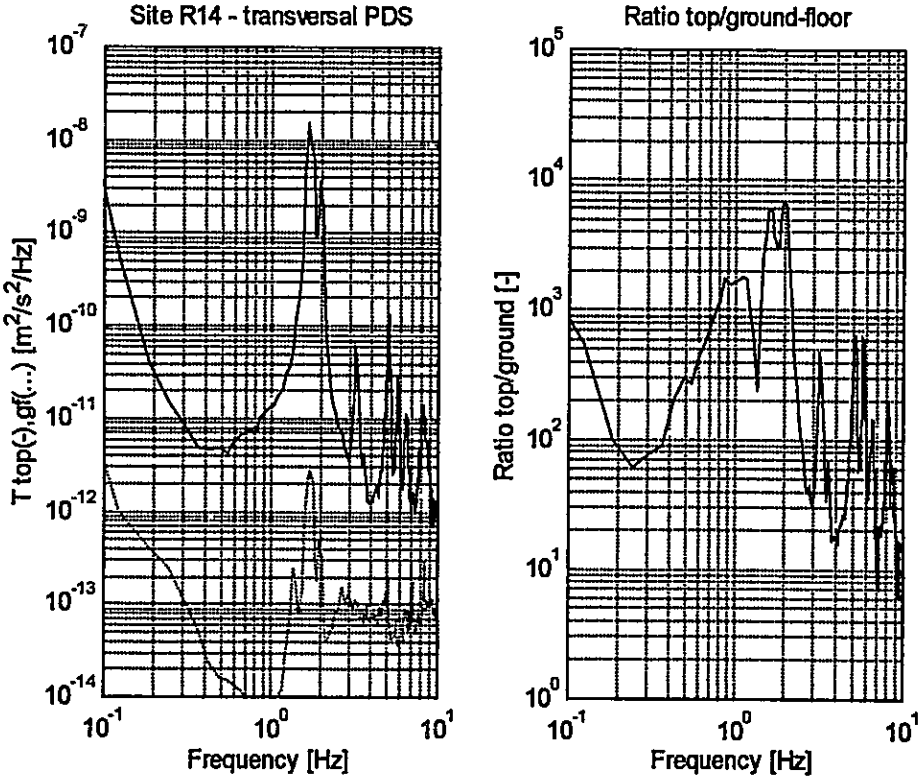
5.3.x Site R14 - Spectral data, spectral ratio, and particle motion.

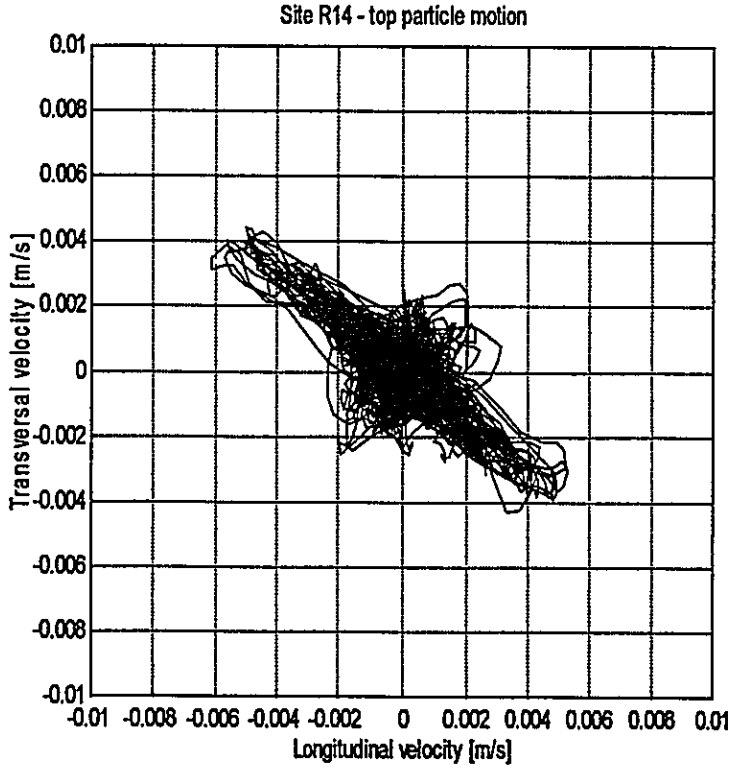




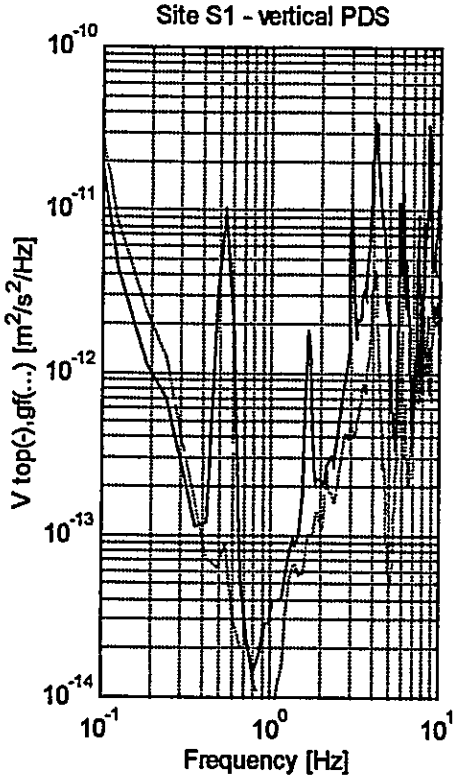


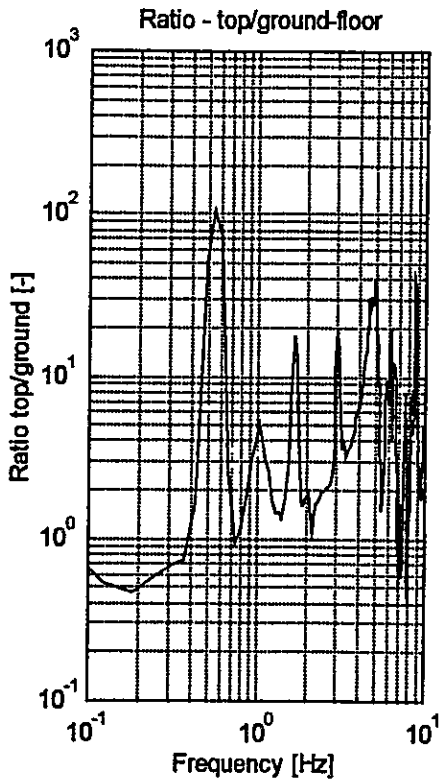


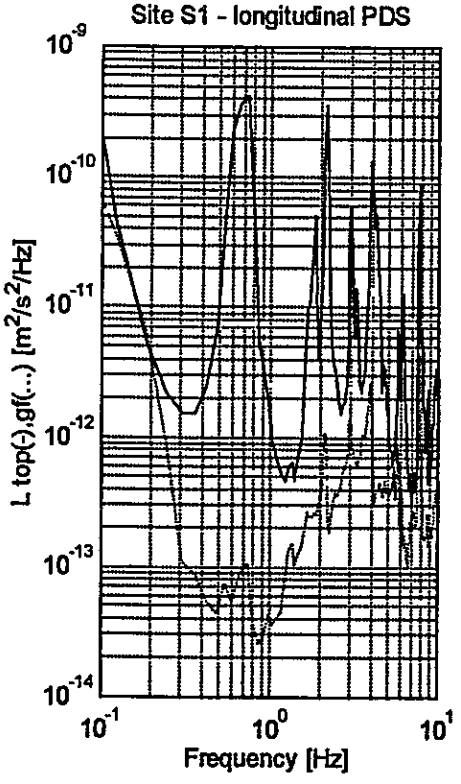

Site R14 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

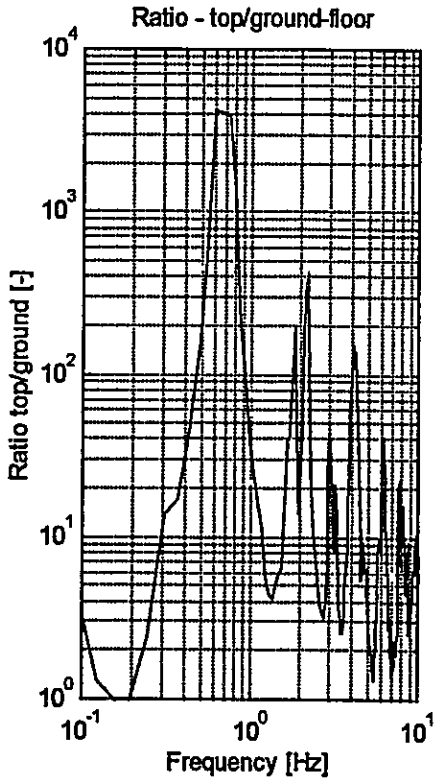

Site R14 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

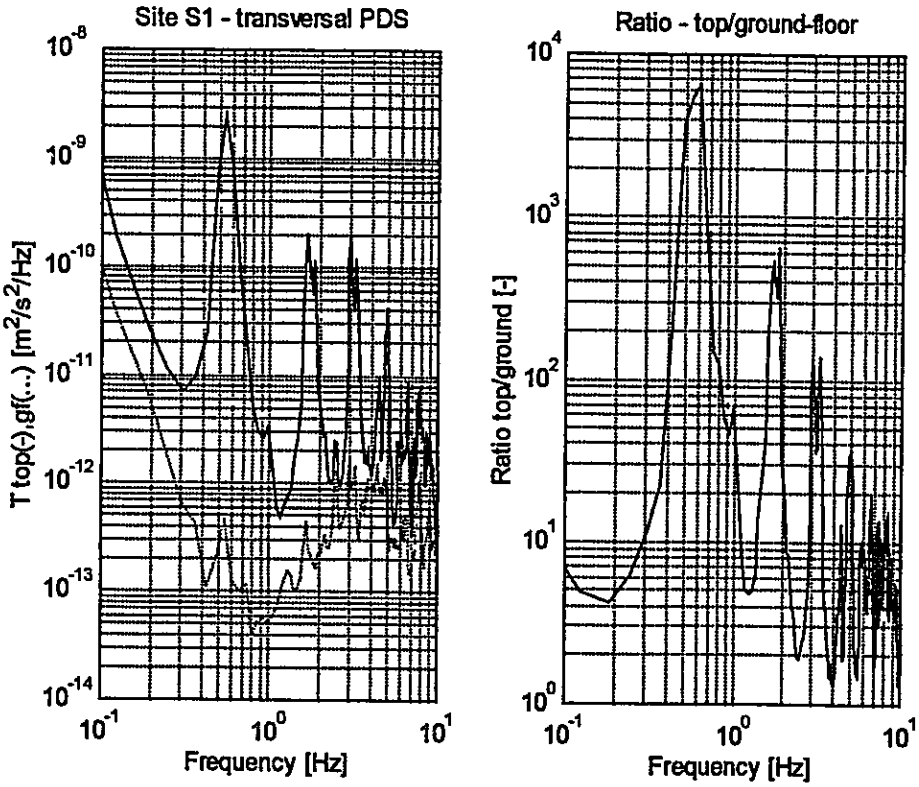
5.3.x Site S1 - Spectral data, spectral ratio, and particle motion.

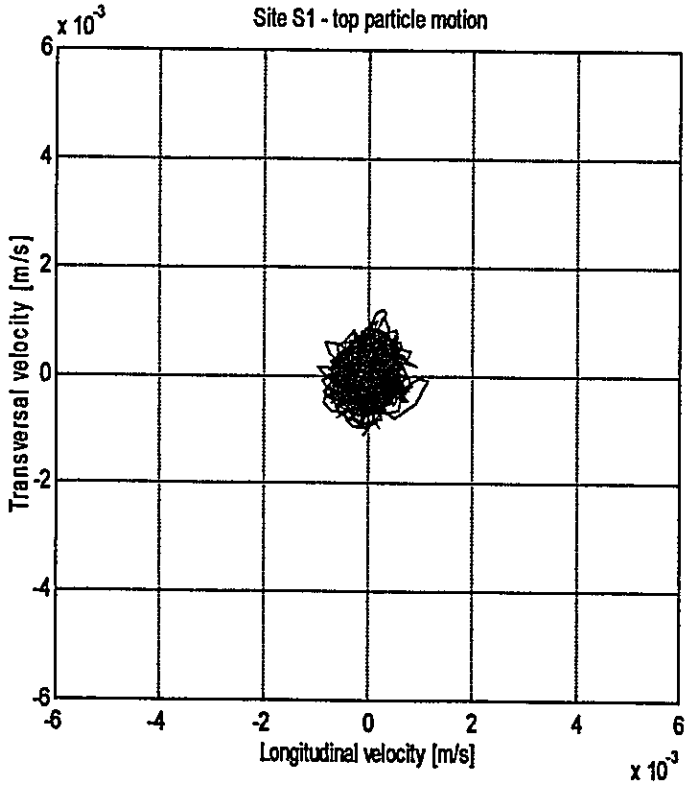




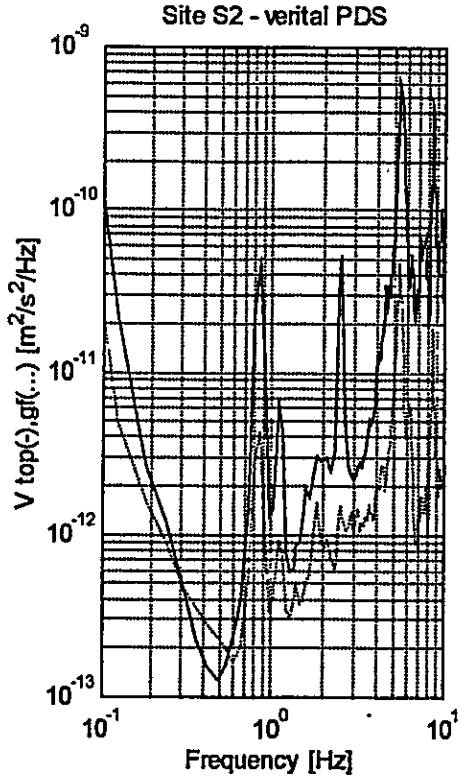


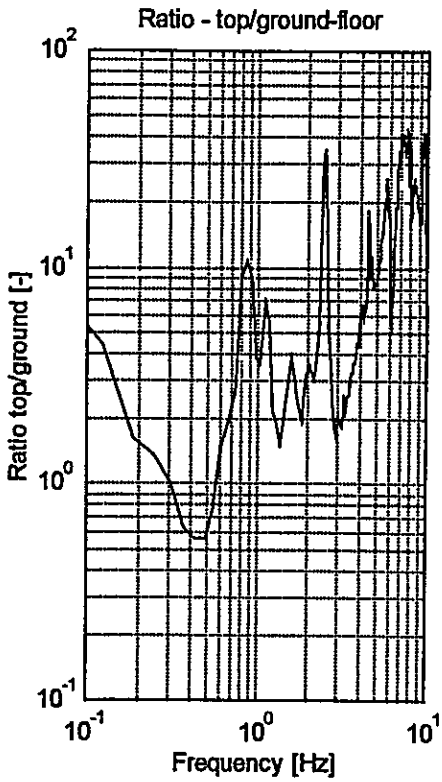


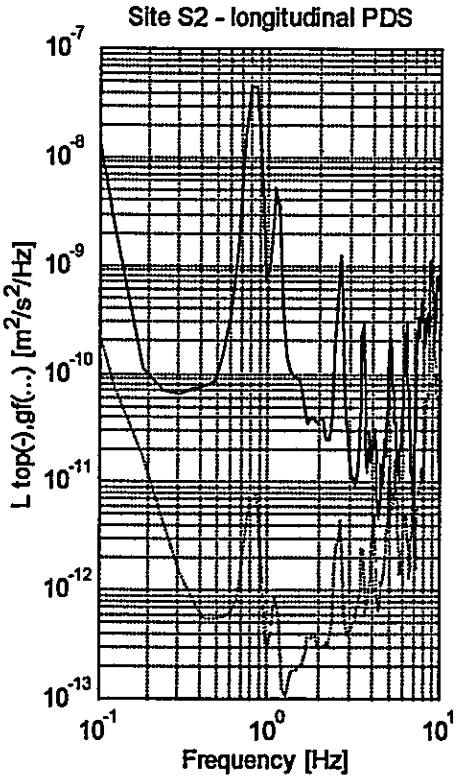

Site S1 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

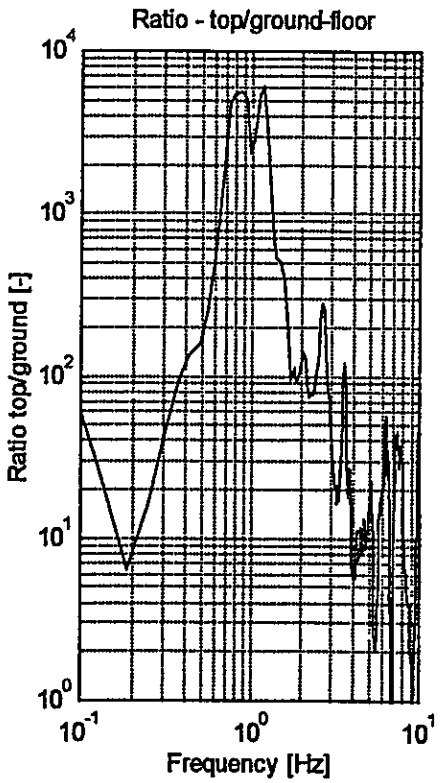

Site S1 - top particle motion
x 10⁻³
Transversal velocity [m/s]
Longitudinal velocity [m/s]
x 10⁻³

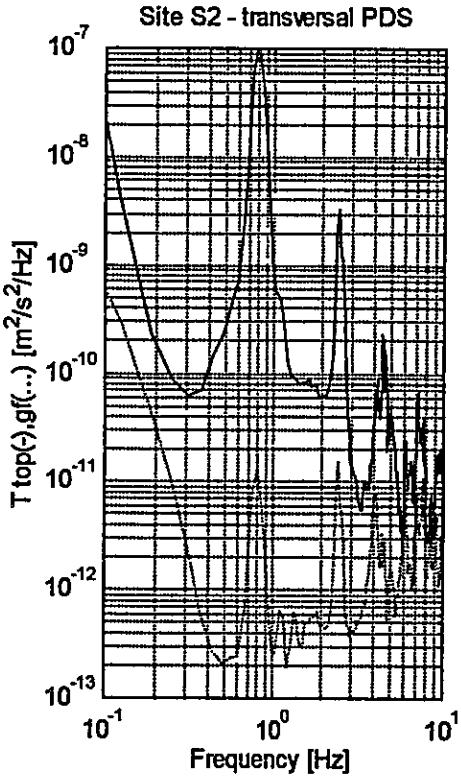
5.3.x Site S2 - Spectral data, spectral ratio, and particle motion

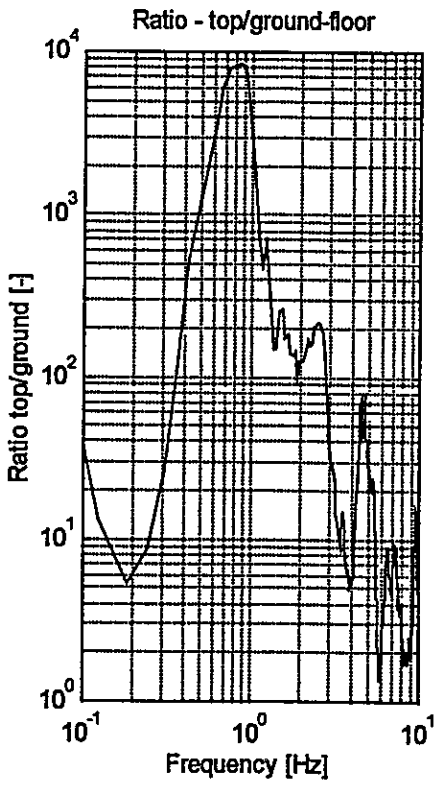


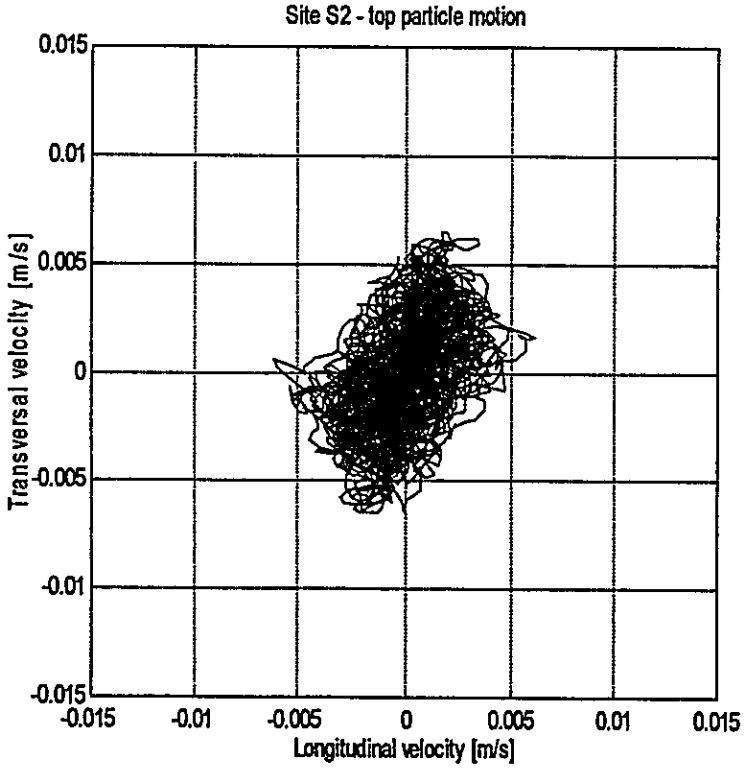




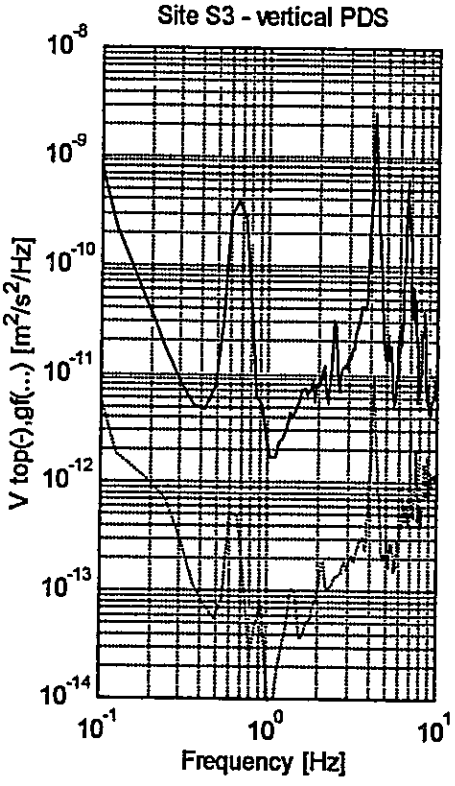


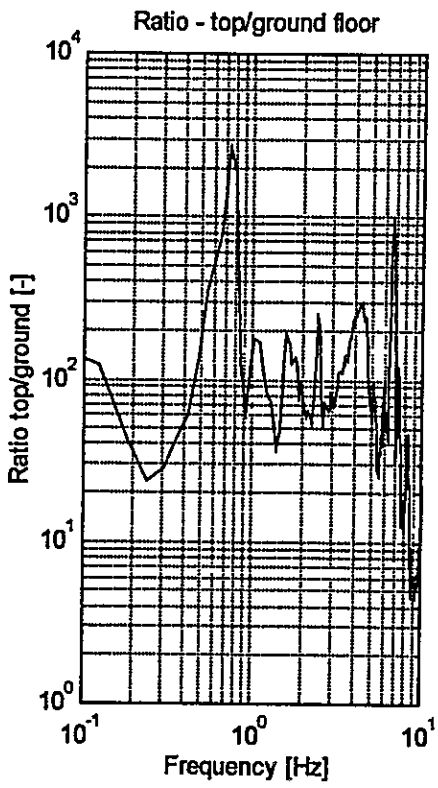

Site S2 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

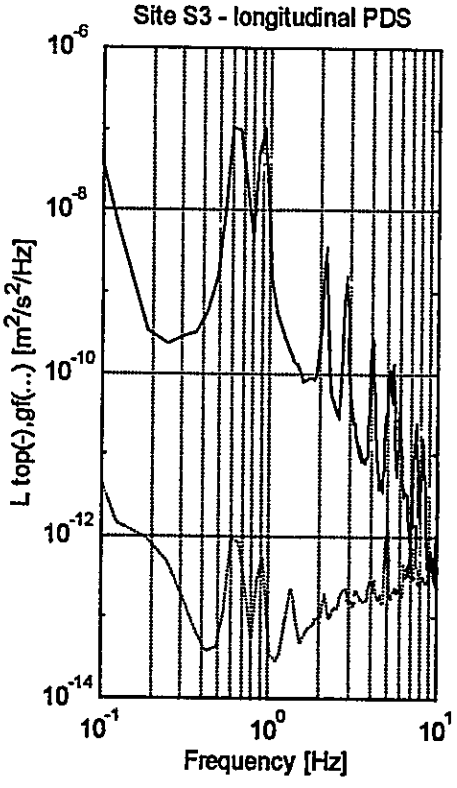

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

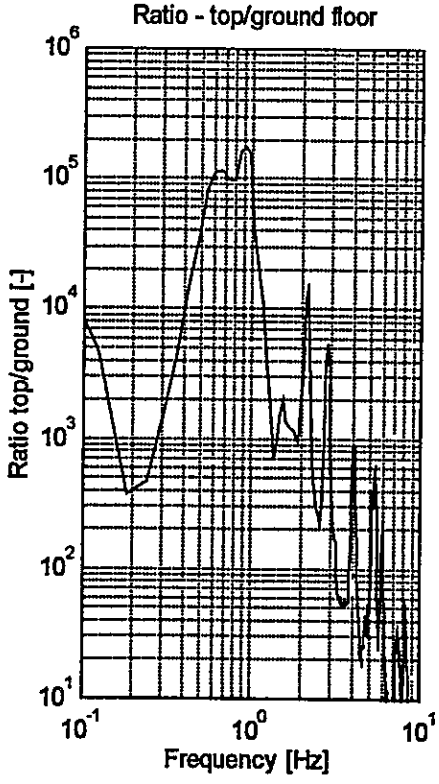

Site S2 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

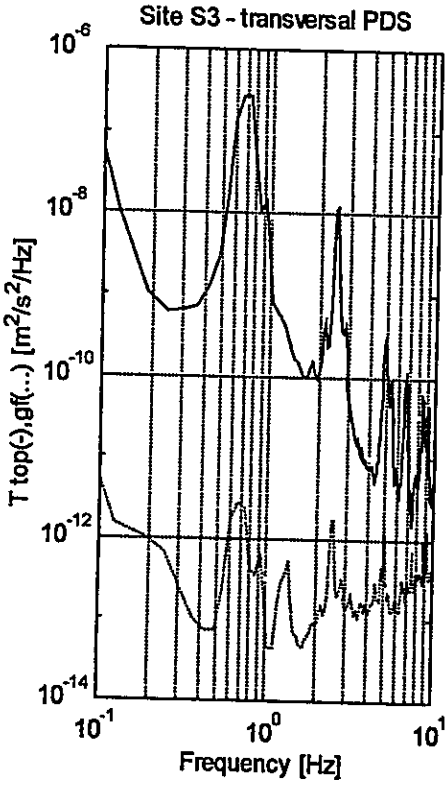
5.3.x Site S3 - Spectral data, spectral ratio, and particle motion.

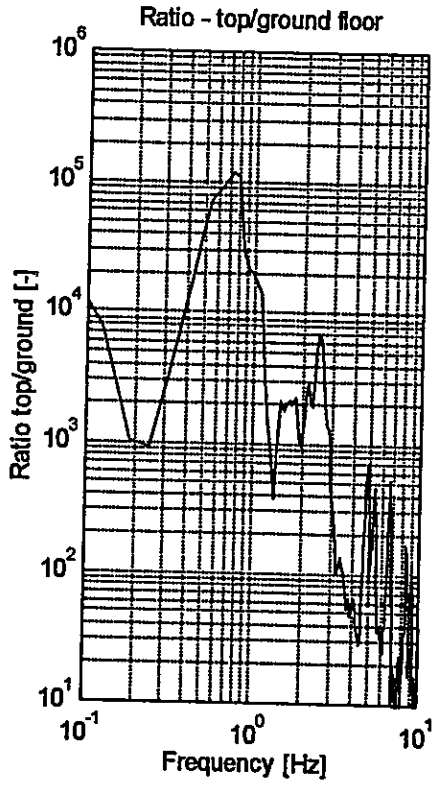


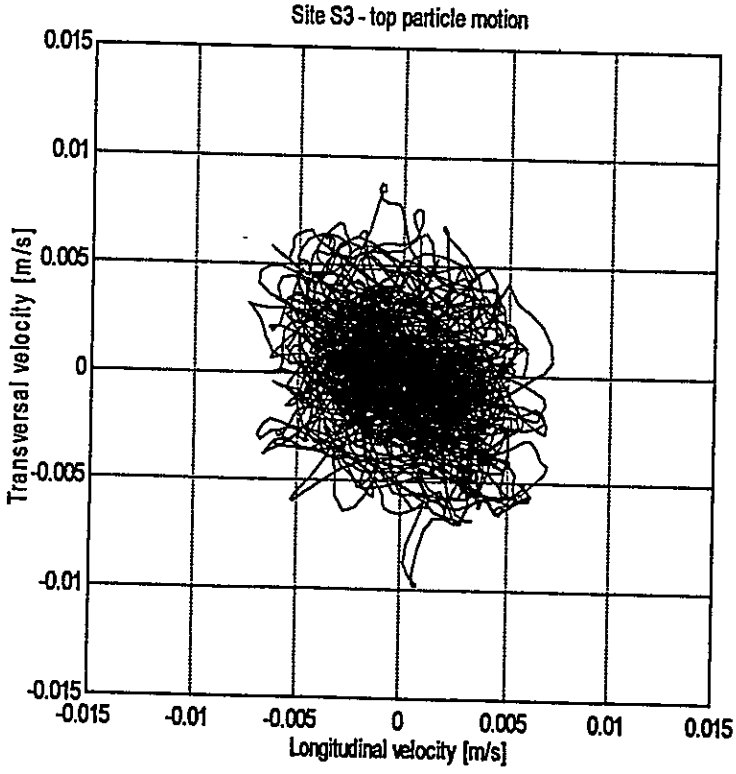




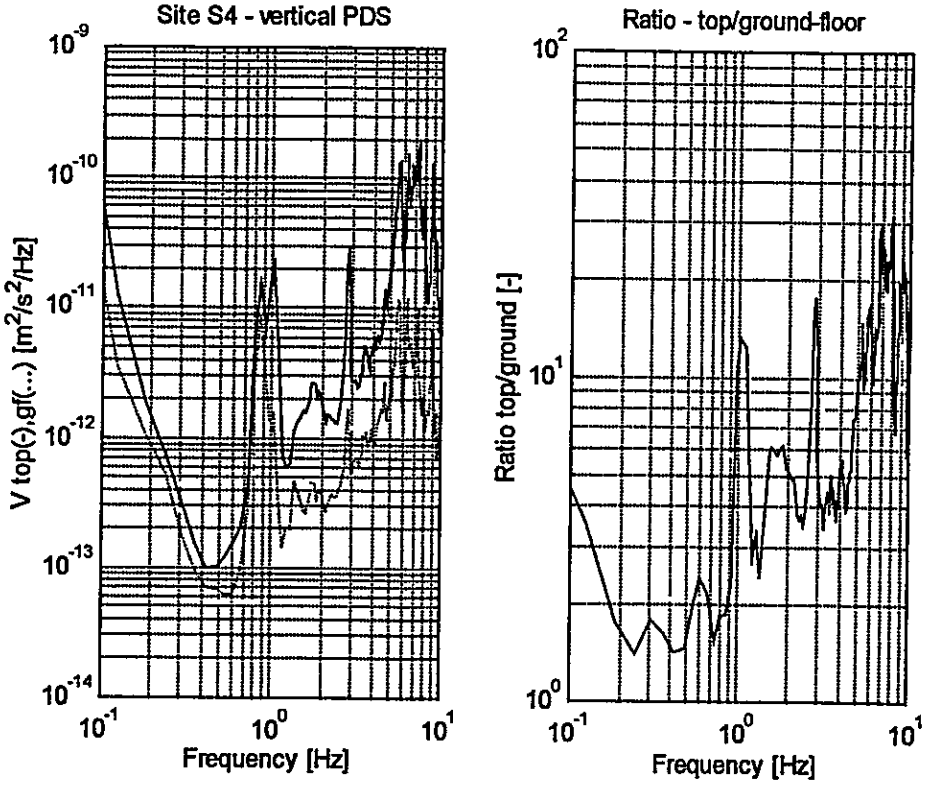


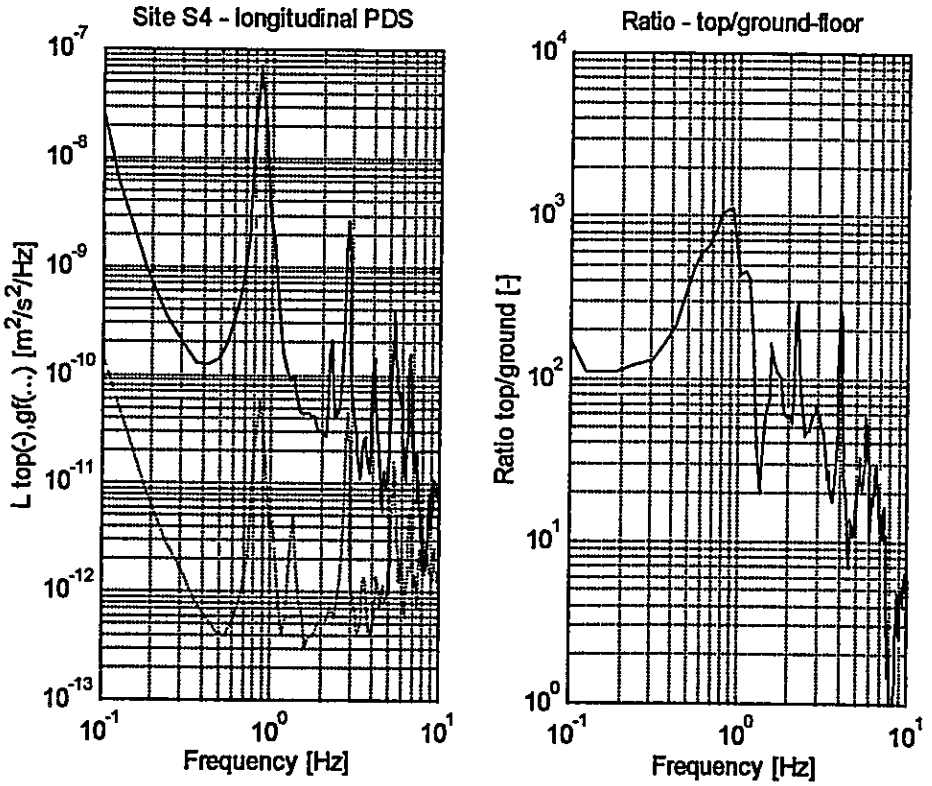

Site S3 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

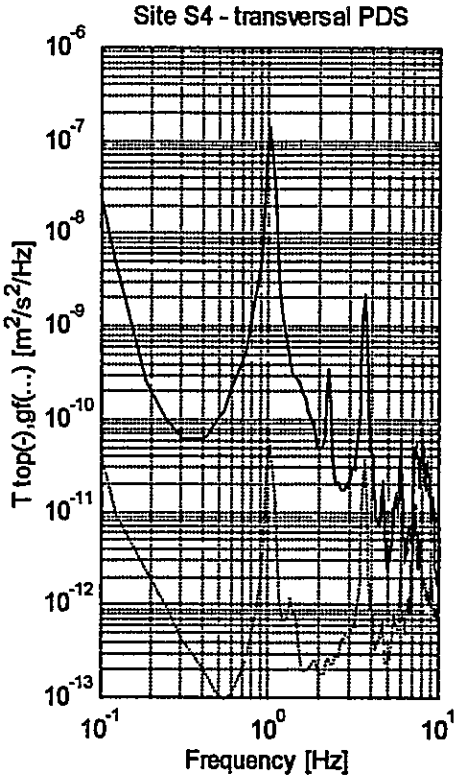

Ratio - top/ground floor
Ratio top/ground [-]
Frequency [Hz]

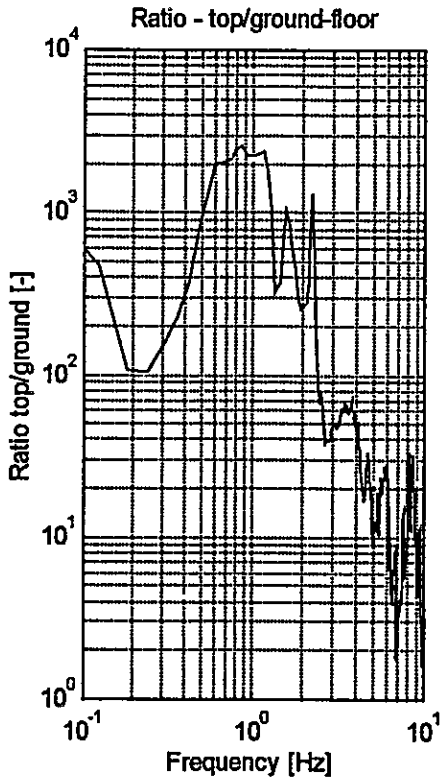

Site S3 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

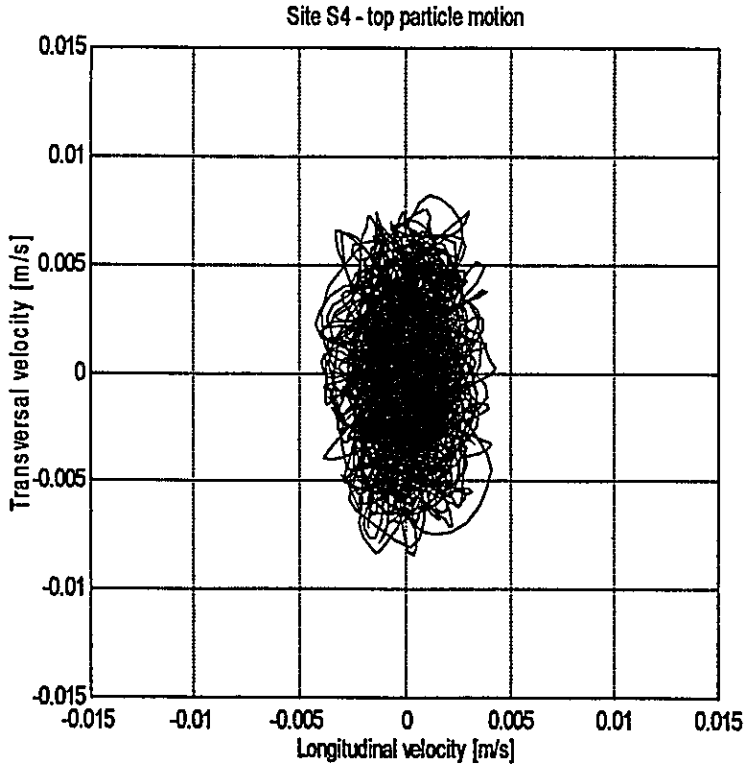
5.3.x Site S4 - Spectral data, spectral ratio, and particle motion.



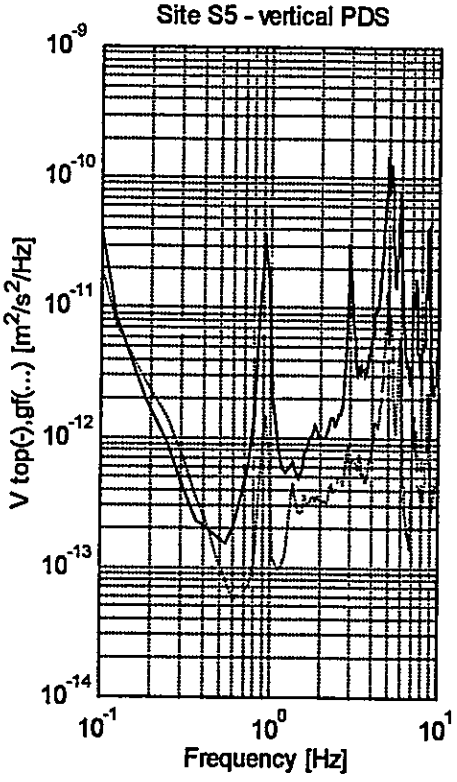


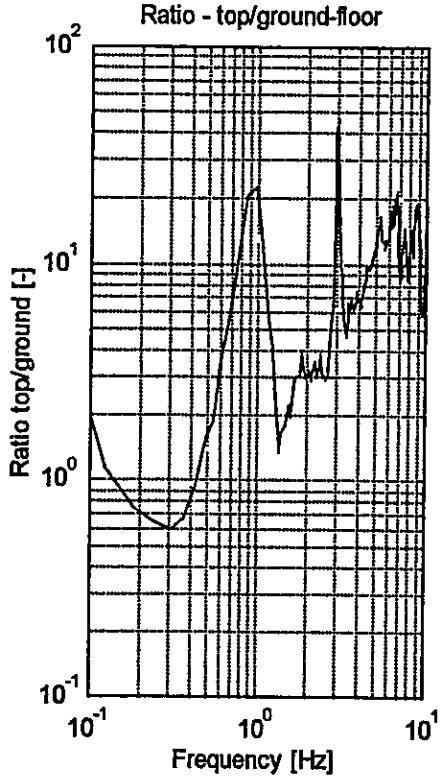

Site S4 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

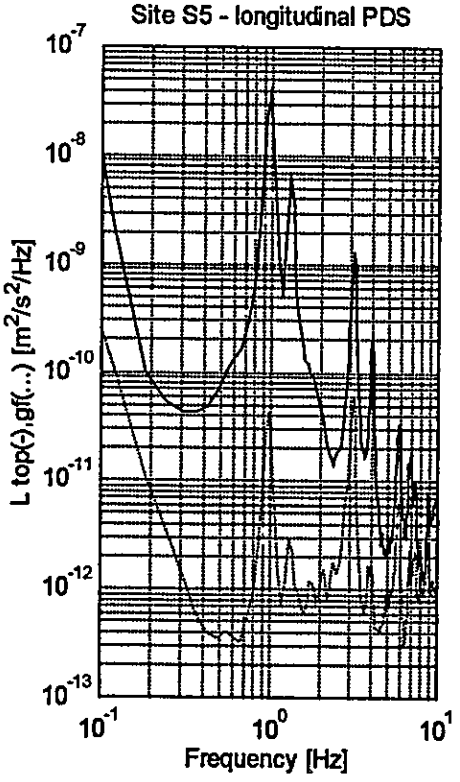

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

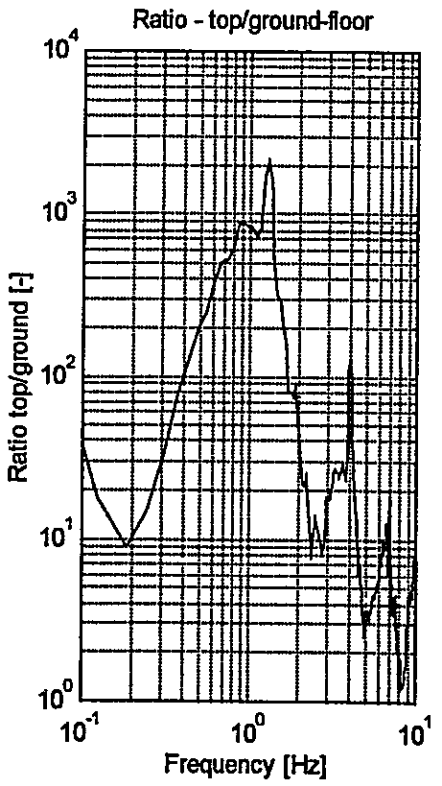

Site S4 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

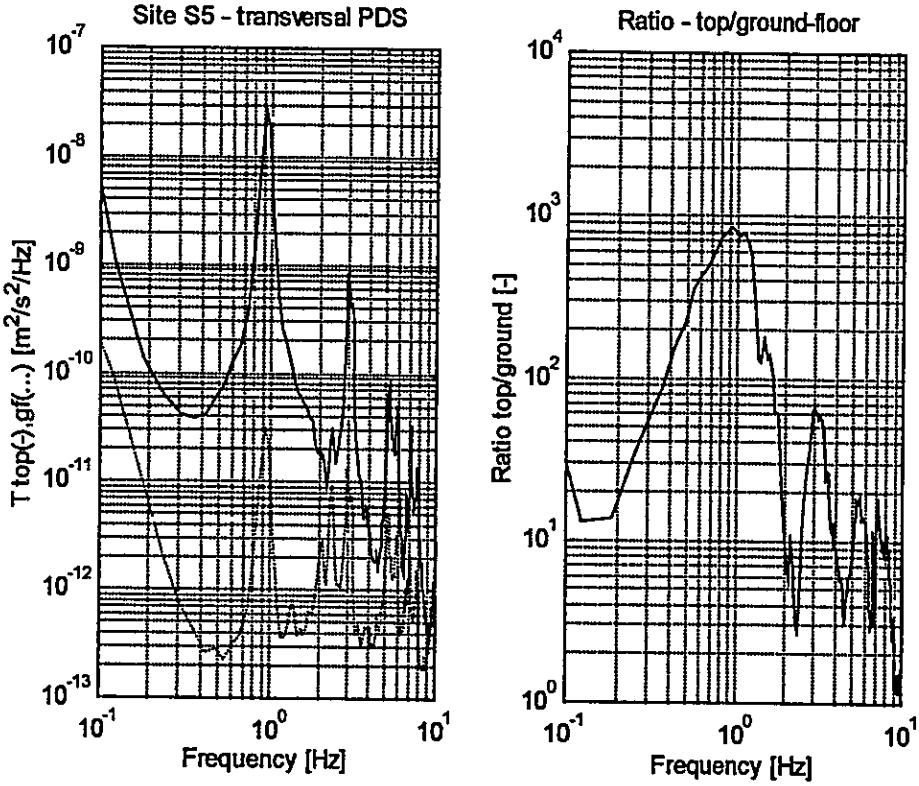
5.3.x Site S5 - Spectral data, spectral ratio, and particle motion.

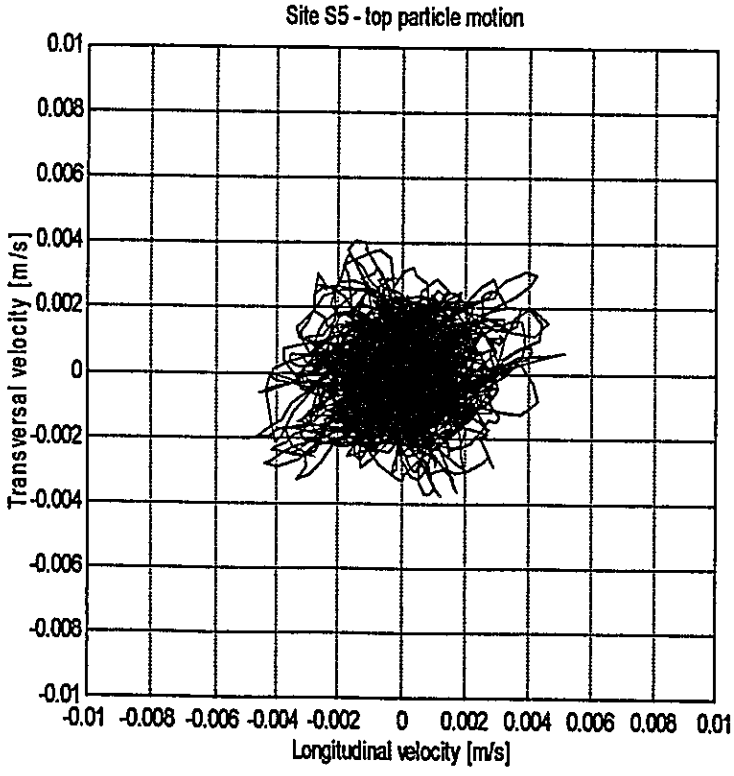




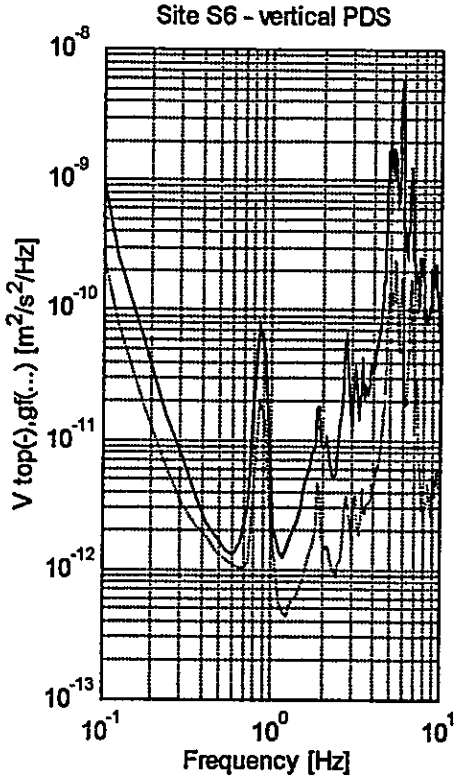


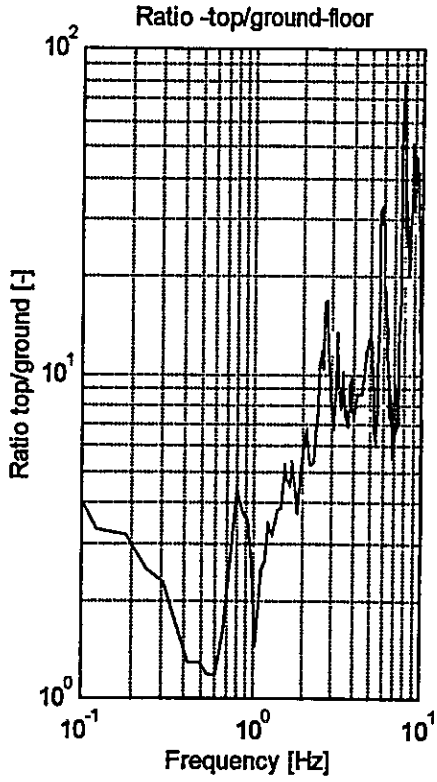


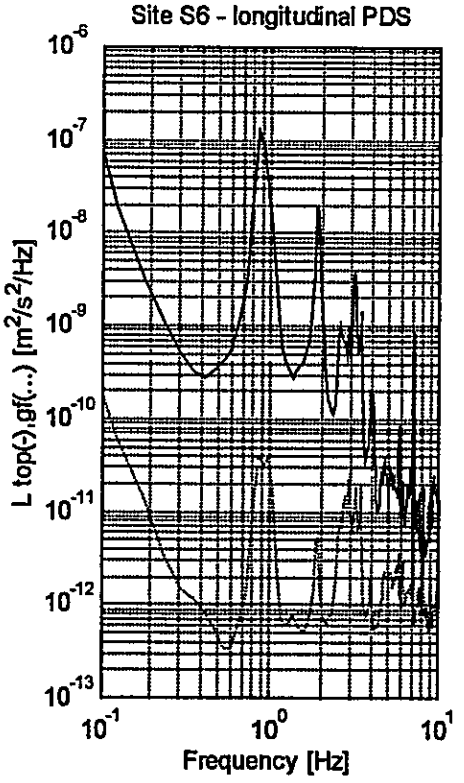

Site S5 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

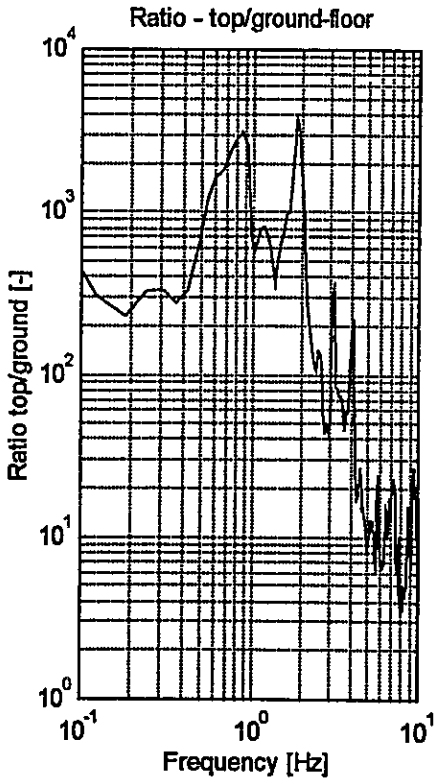

Site S5 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

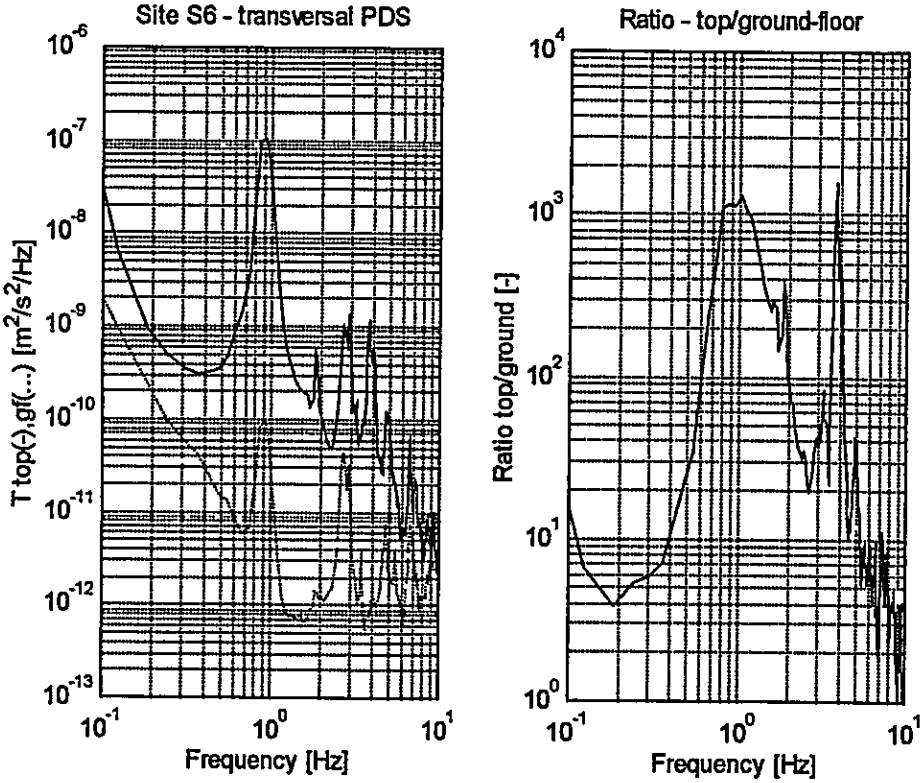
5.3.x Site S6 - Spectral data, spectral ratio, and particle motion.

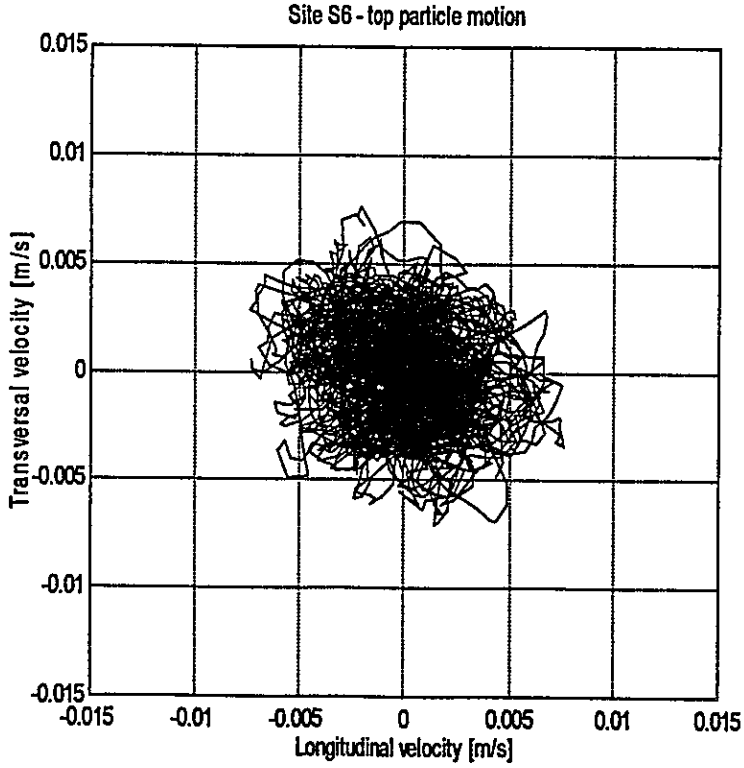




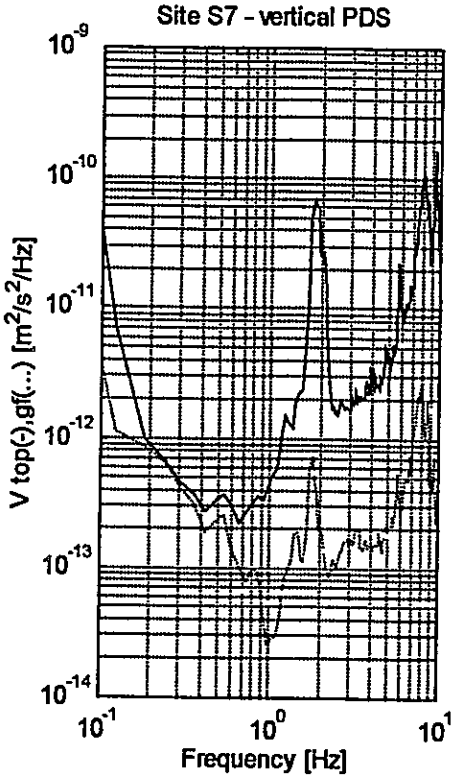


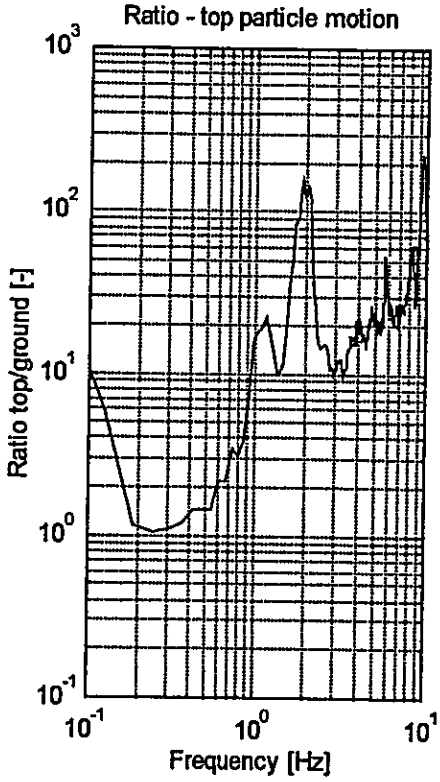


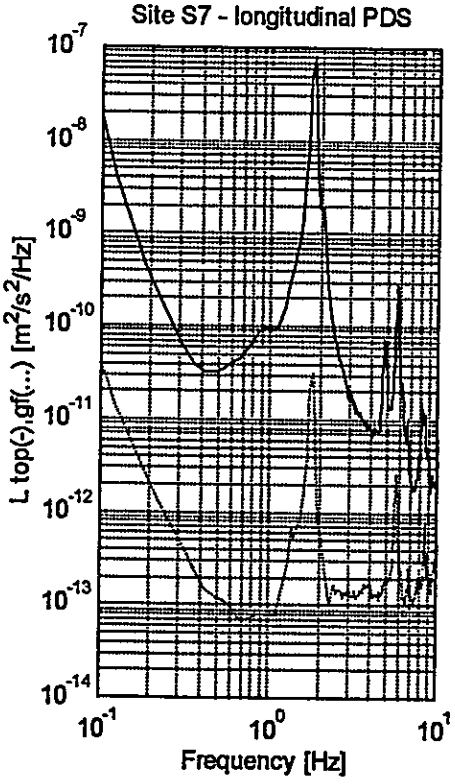

Site S6 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

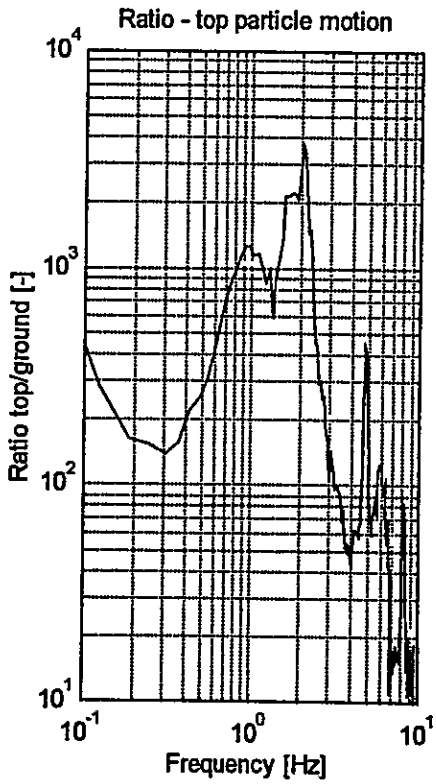

Site S6 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

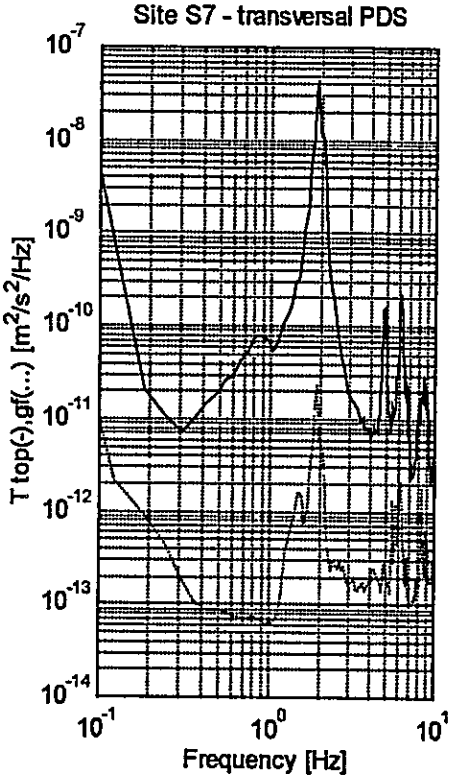
5.3.x Site S7 - Spectral data, spectral ratio, and particle motion.

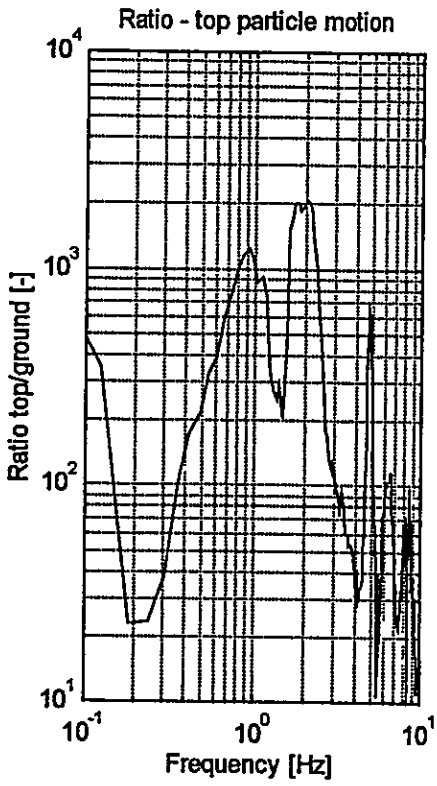


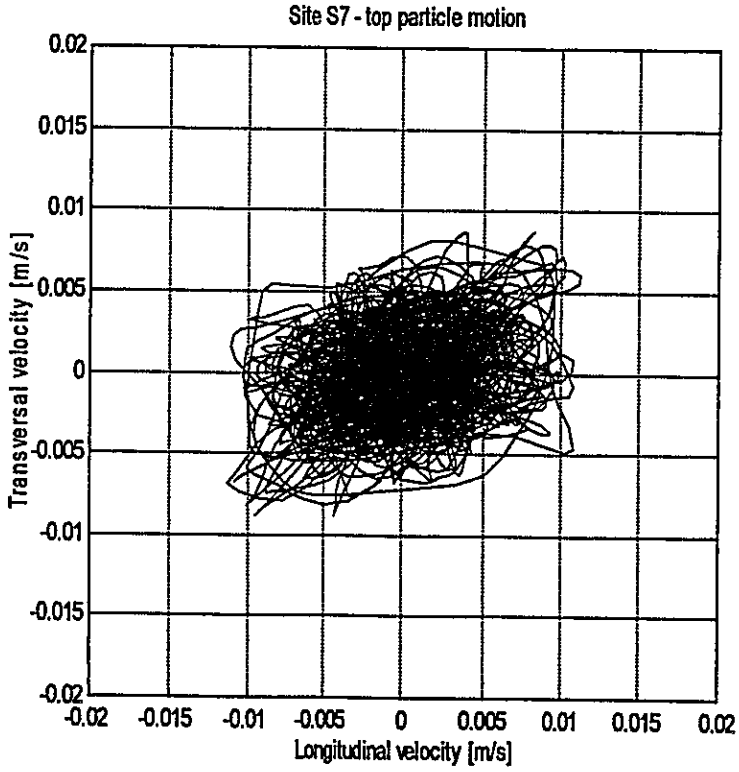




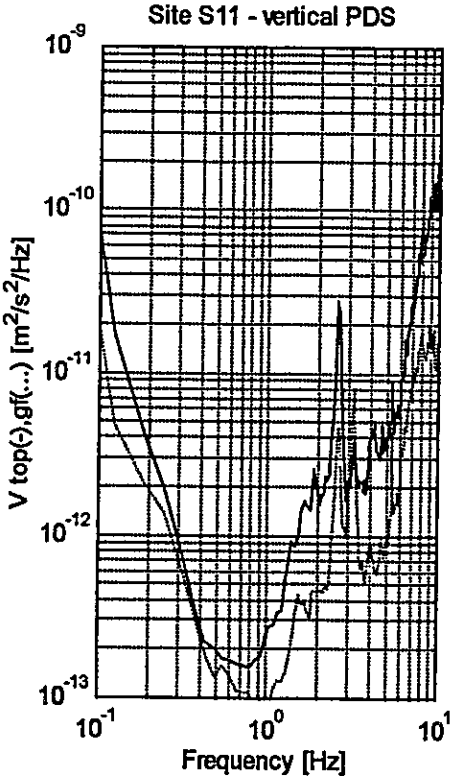


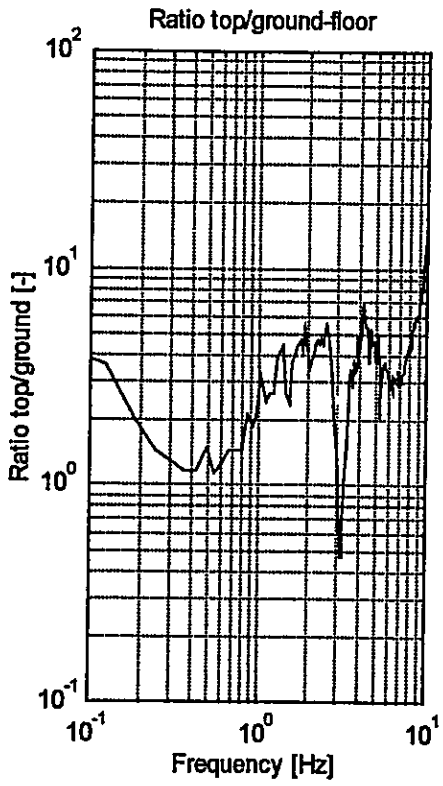

Site S7 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

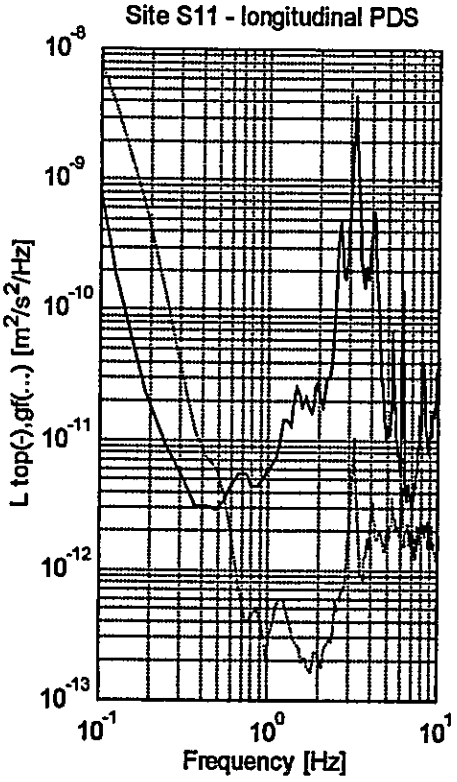

Ratio - top particle motion
Ratio top/ground [-]
Frequency [Hz]

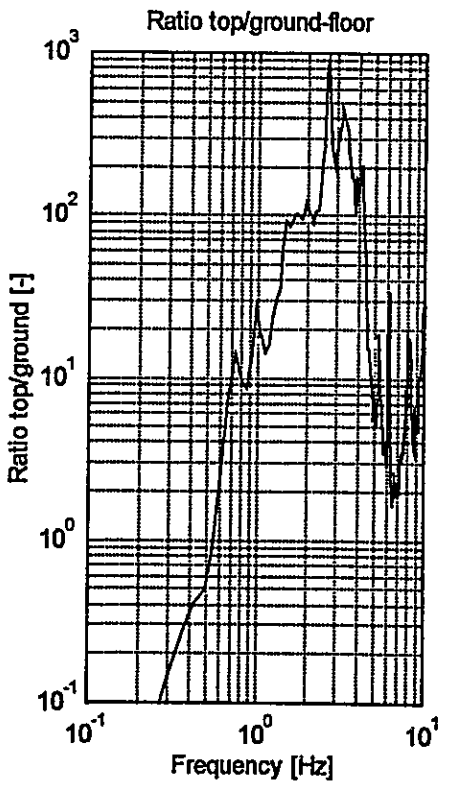

Site S7 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

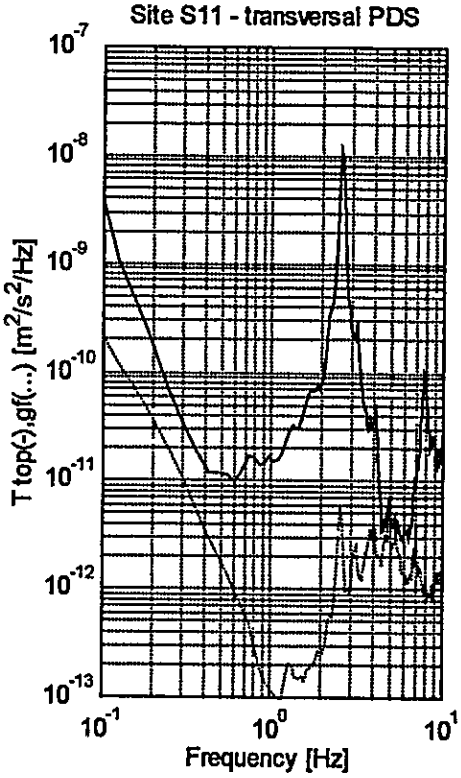
5.3.x Site S11 - Spectral data, spectral ratio, and particle motion.

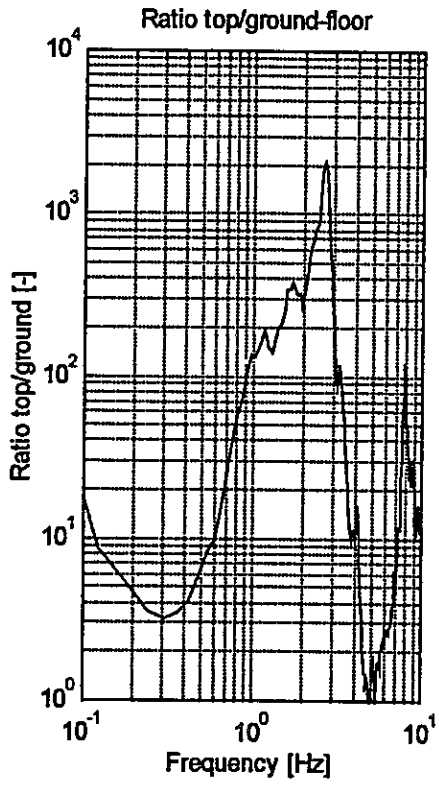


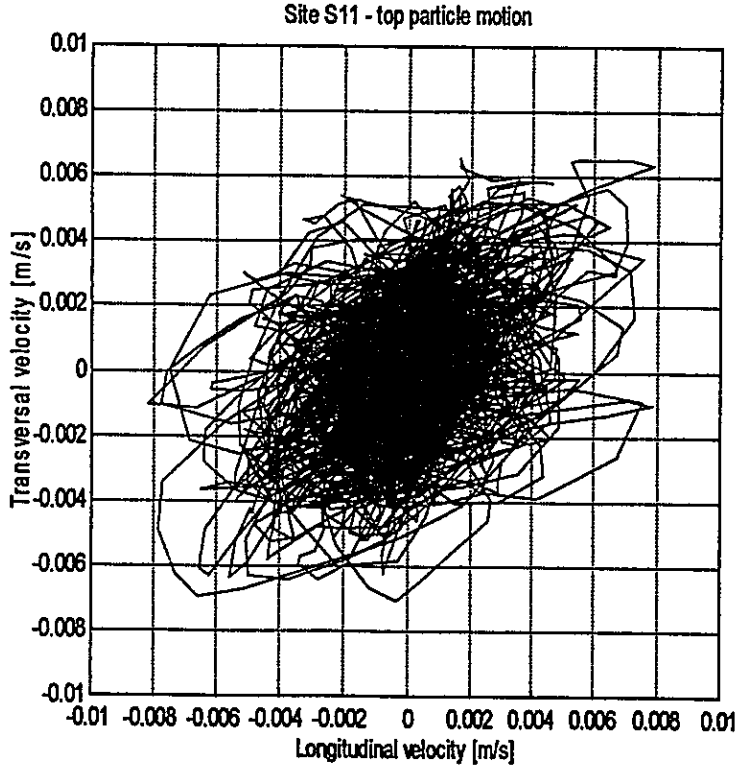




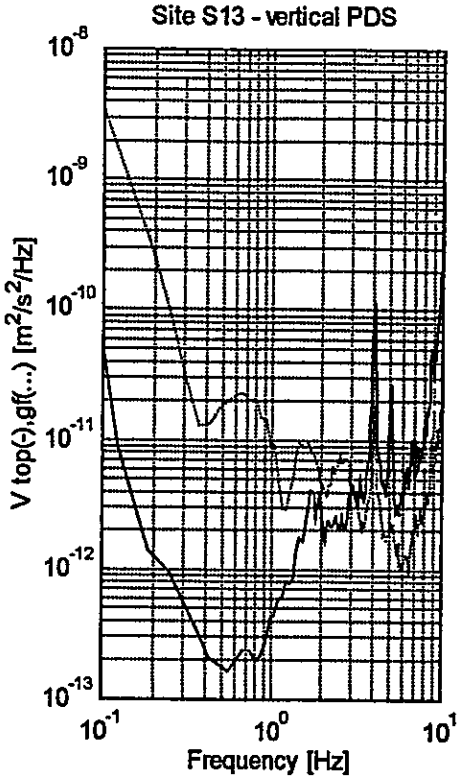


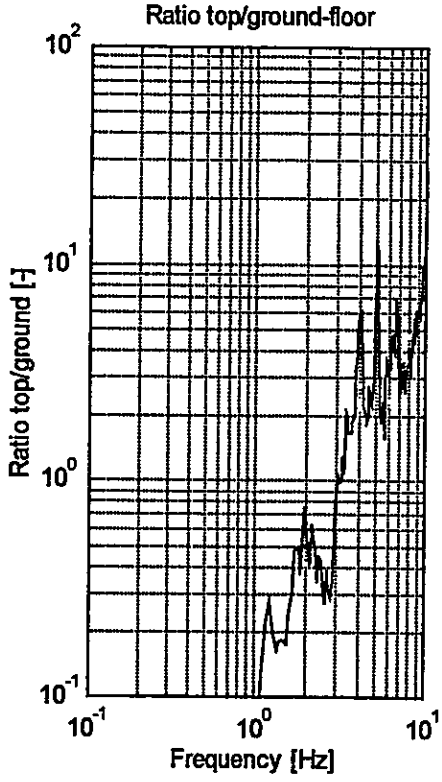

Site S11 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

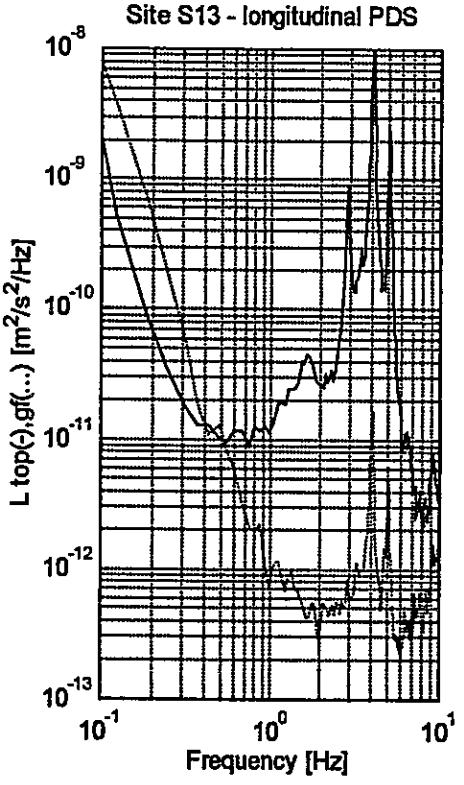

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

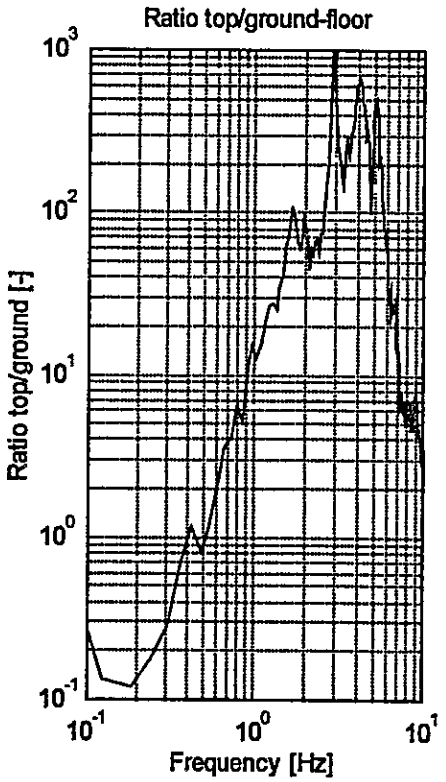

Site S11 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

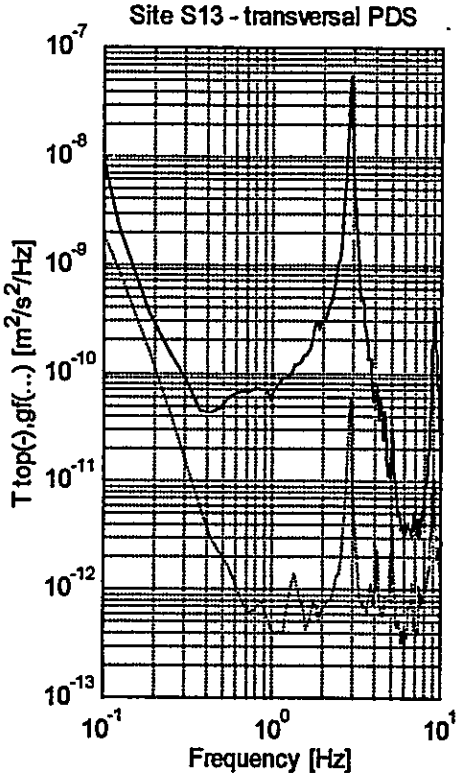
5.3.x Site S13 - Spectral data, spectral ratio, and particle motion.

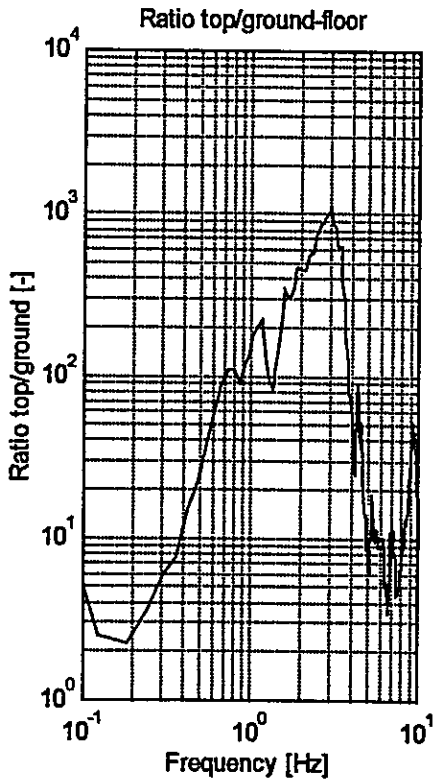


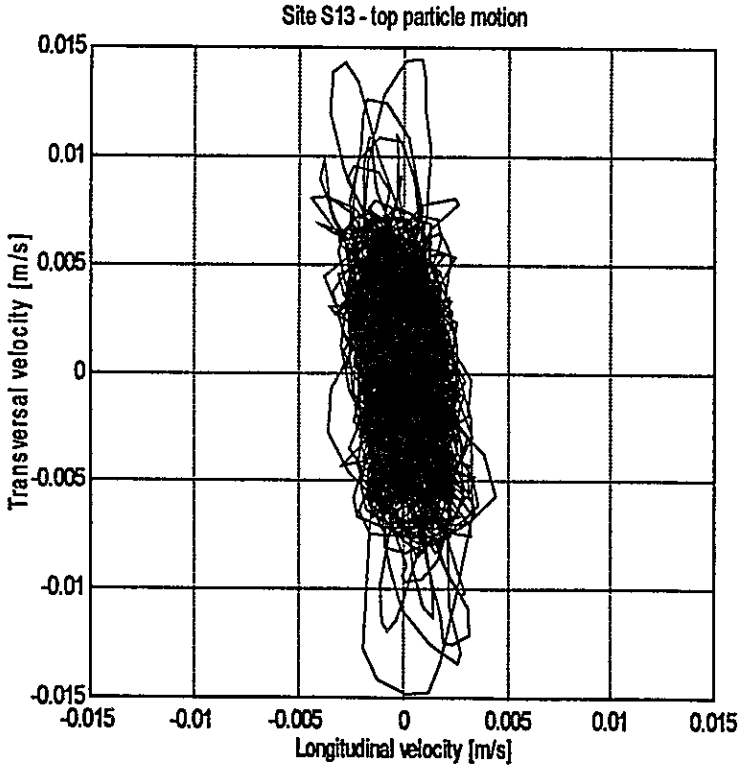




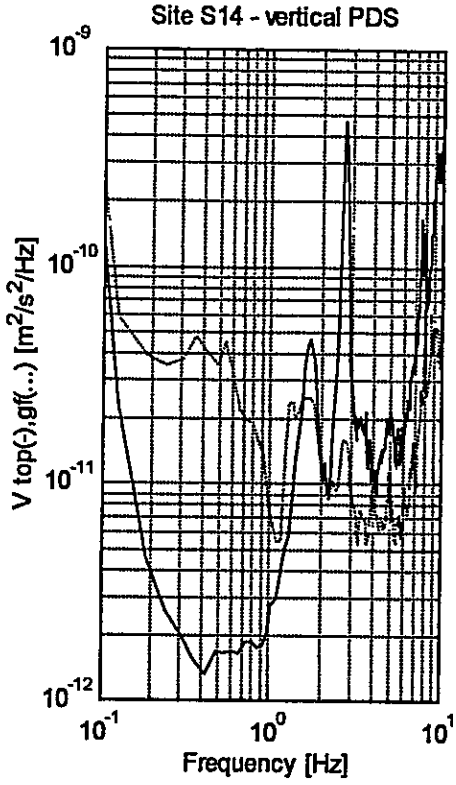


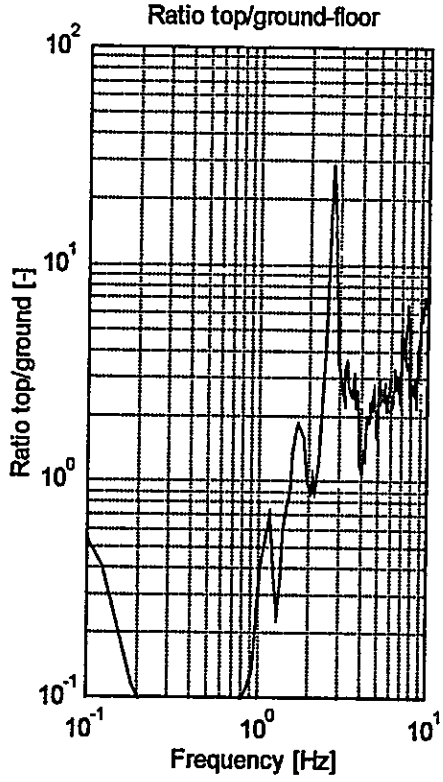

Site S13 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

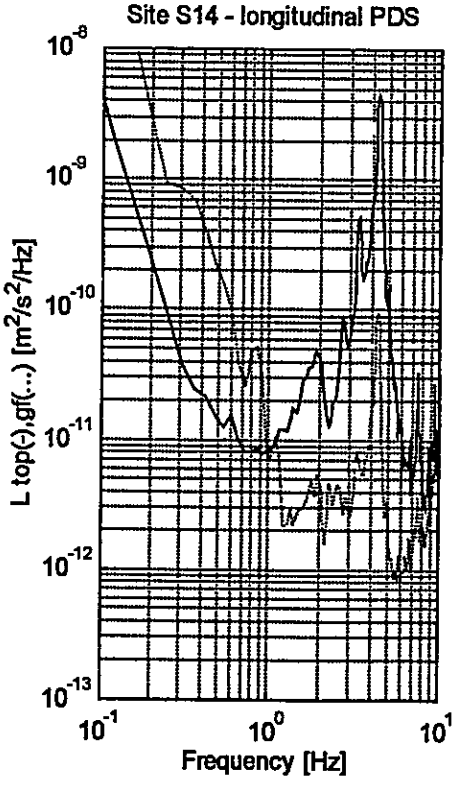

Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

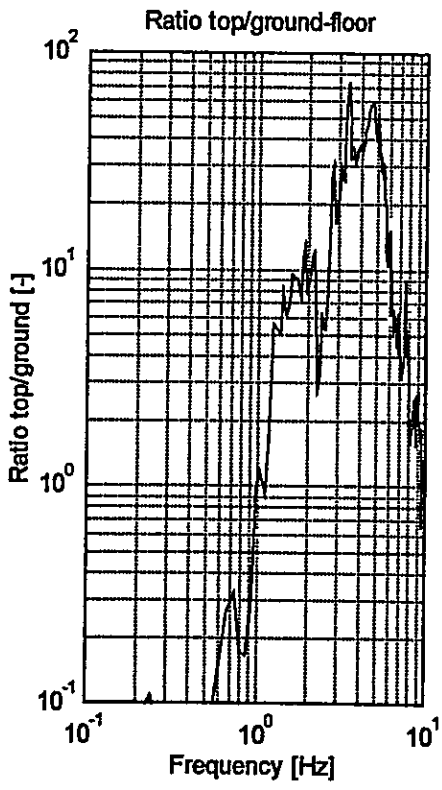

Site S13 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

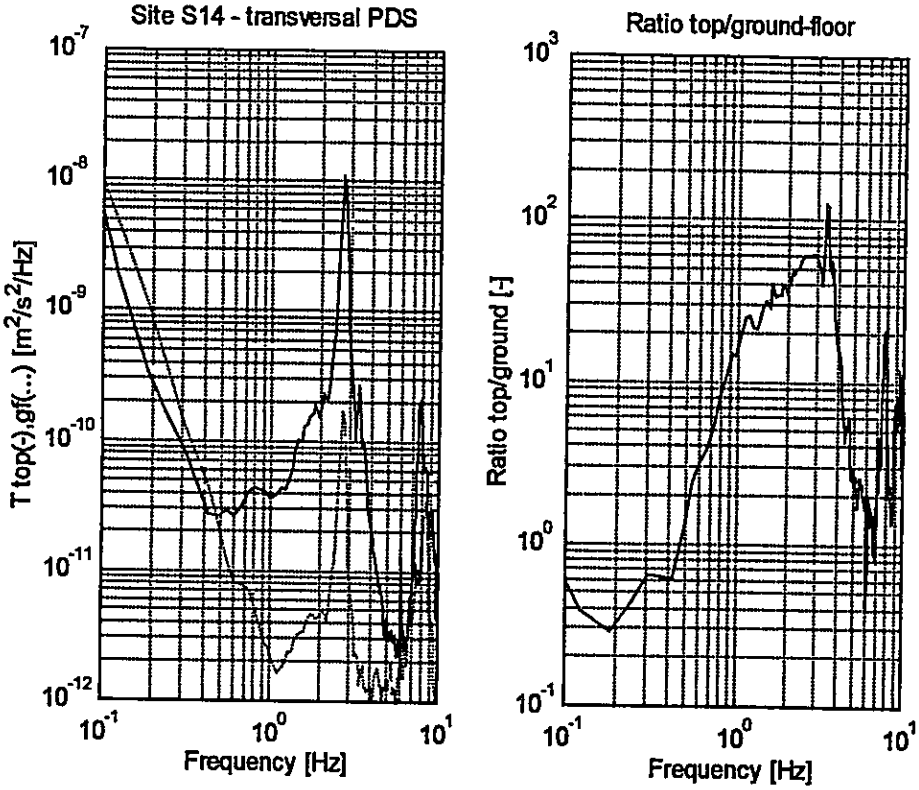
5.3.x Site S14 - Spectral data, spectral ratio, and particle motion.

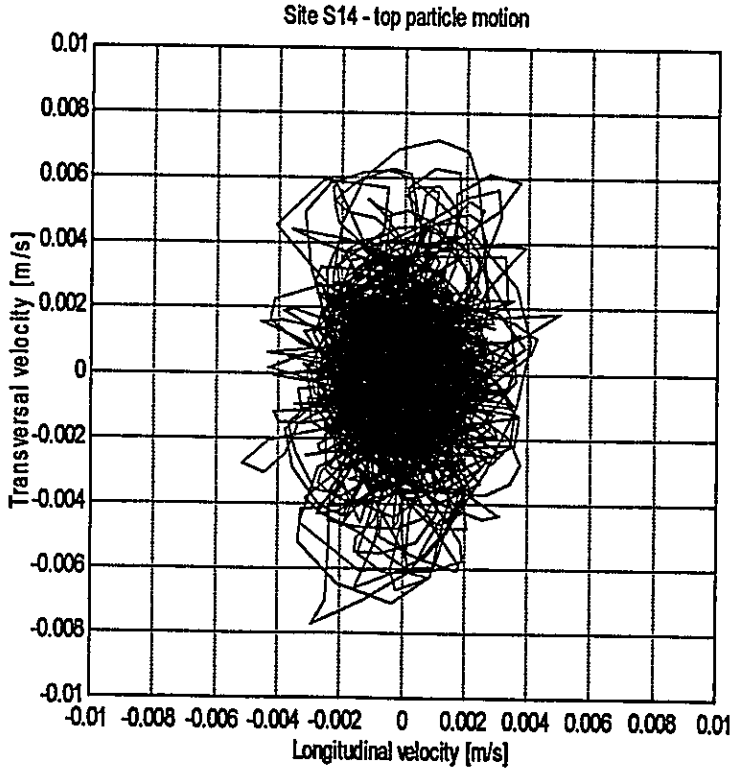




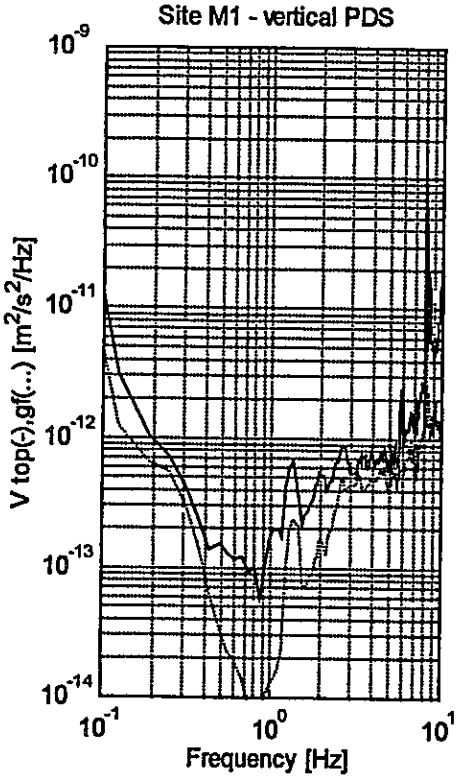


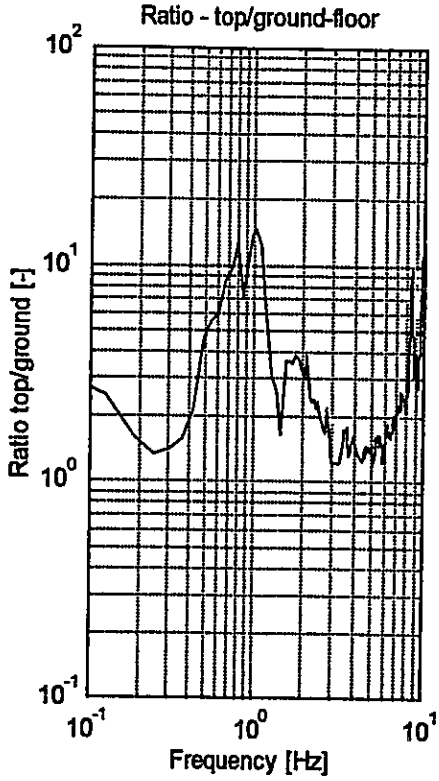


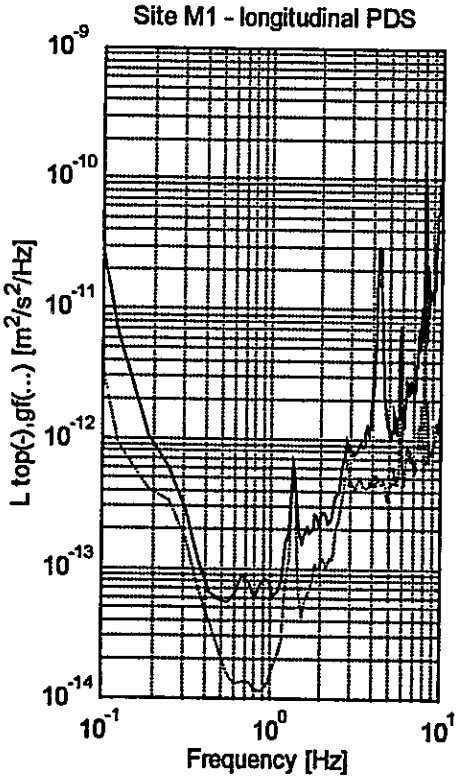

Site S14 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]
Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

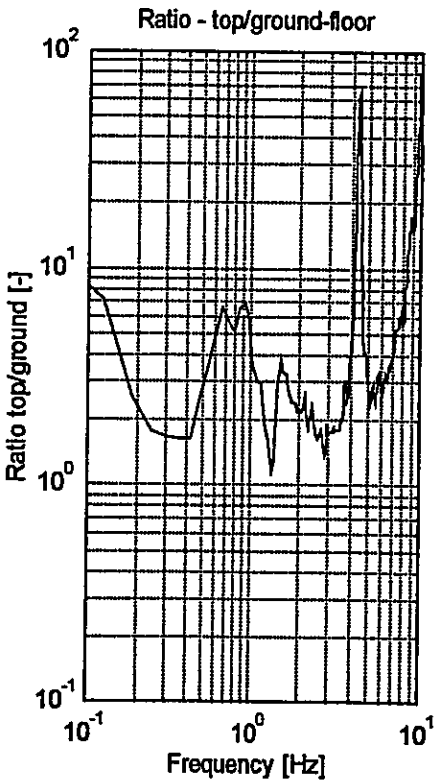

Site S14 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

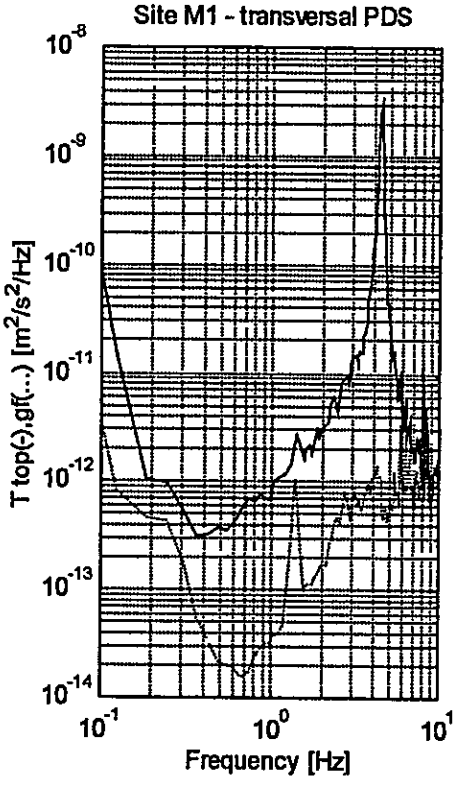
5.3.x Site M1 - Spectral data, spectral ratio, and particle motion.

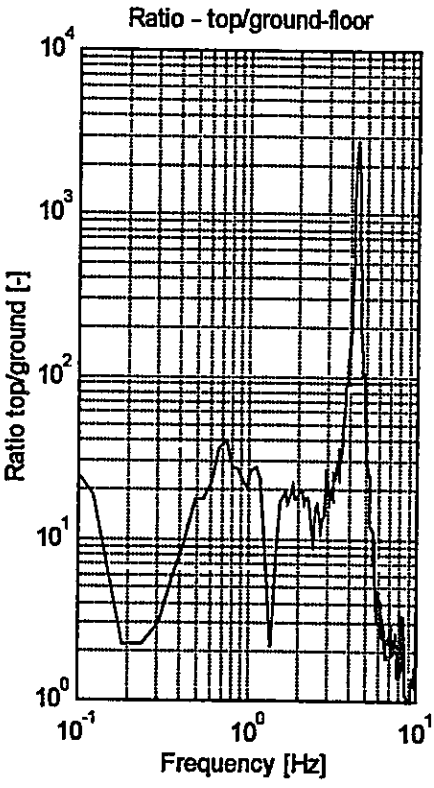


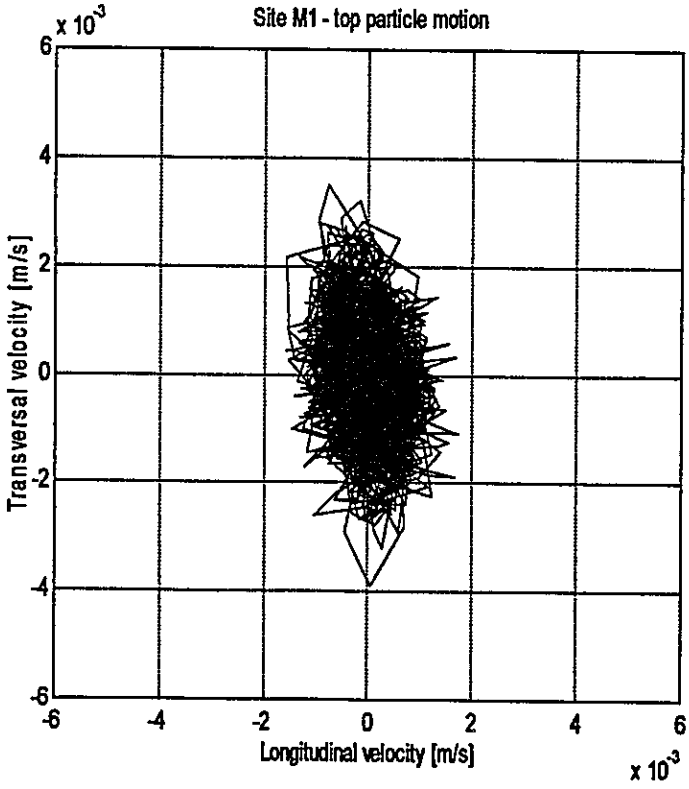




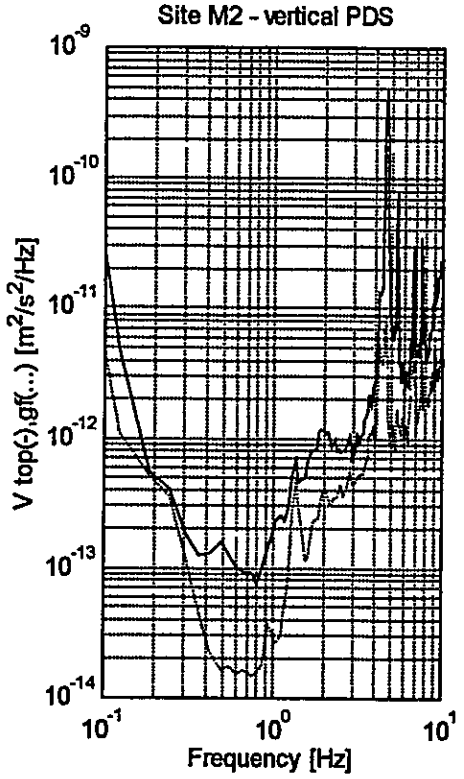


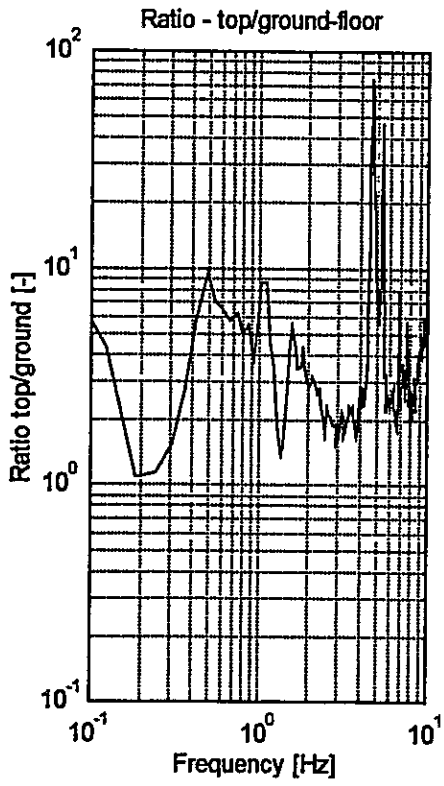

Site M1 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

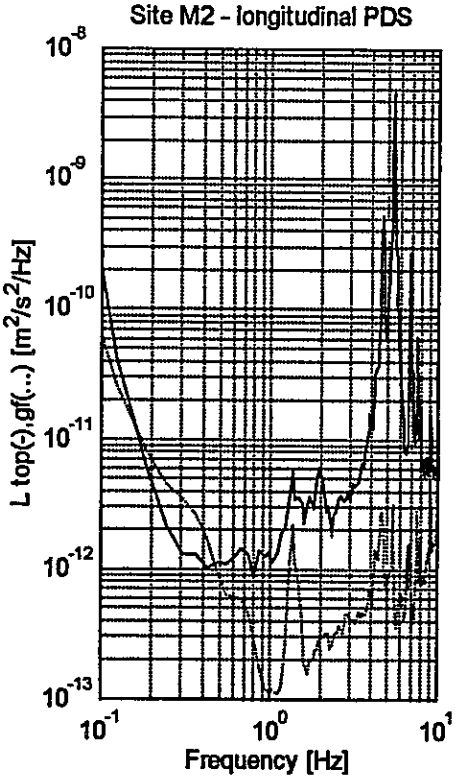

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

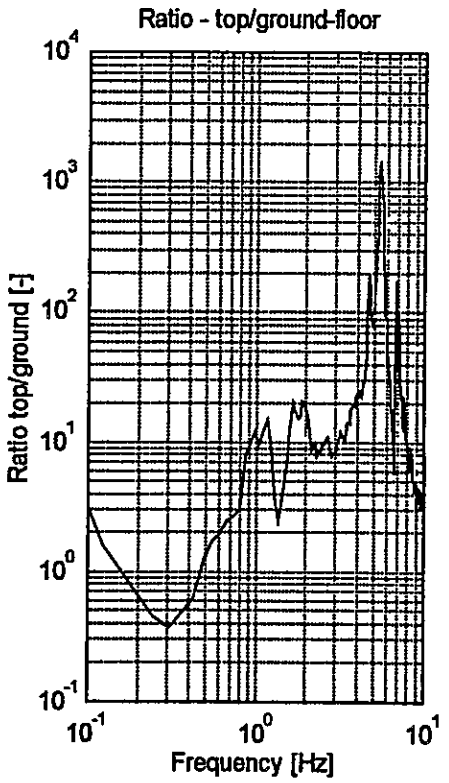

Site M1 - top particle motion
x 10⁻³
Transversal velocity [m/s]
Longitudinal velocity [m/s]
x 10⁻³

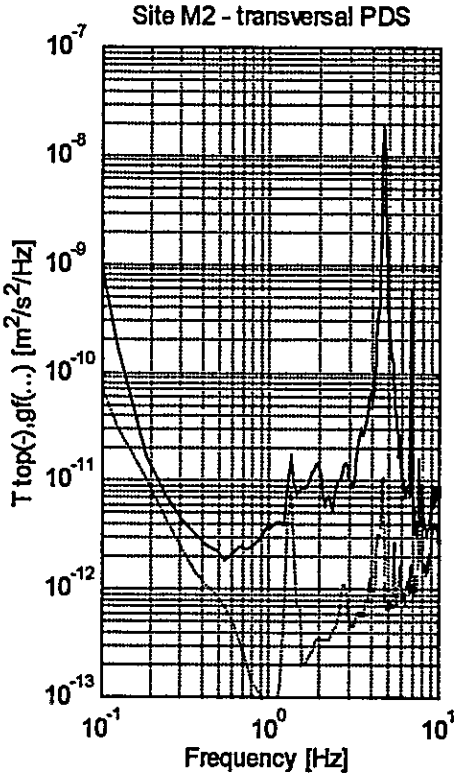
5.3.x Site M2 - Spectral data, spectral ratio, and particle motion.

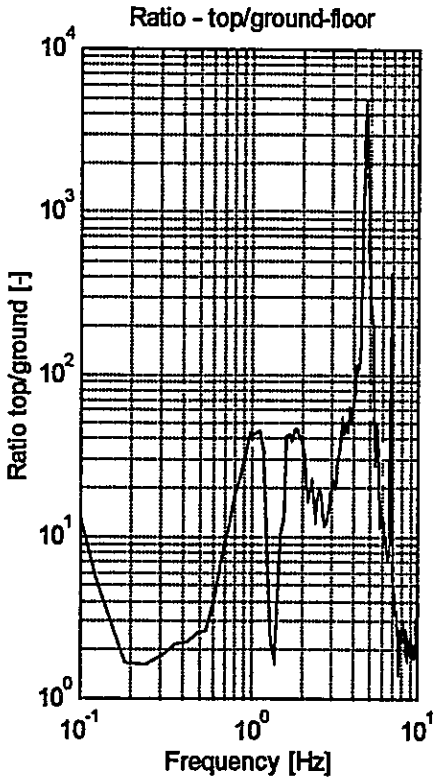


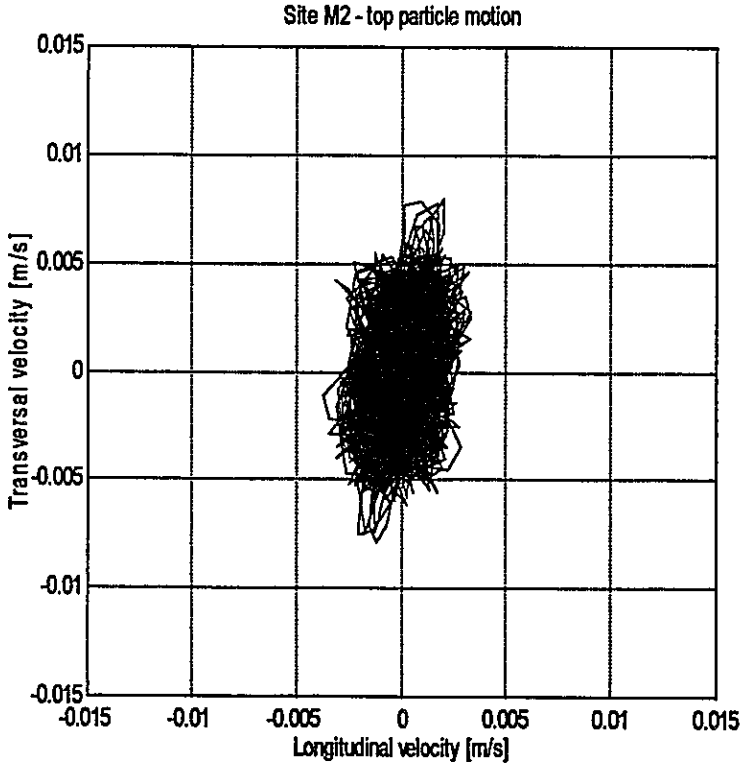




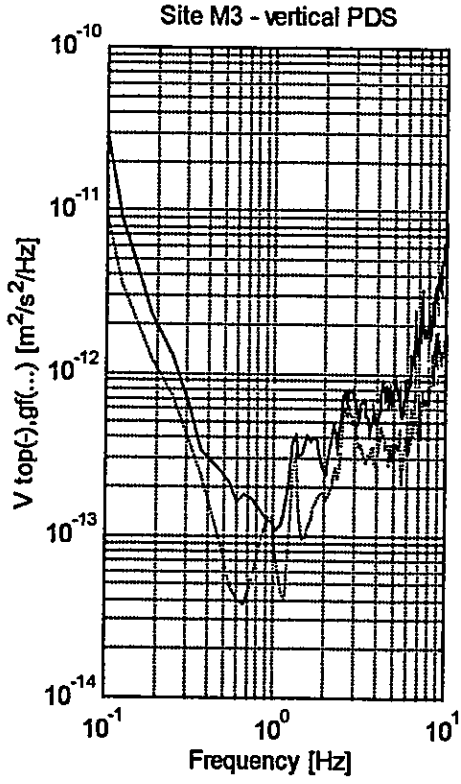


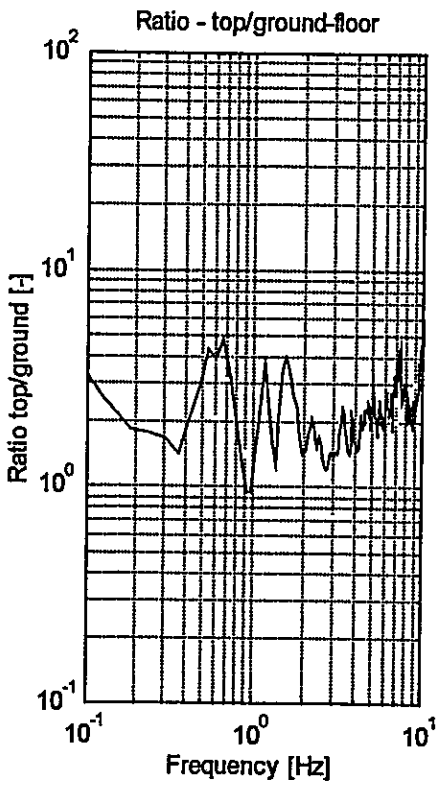

Site M2 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

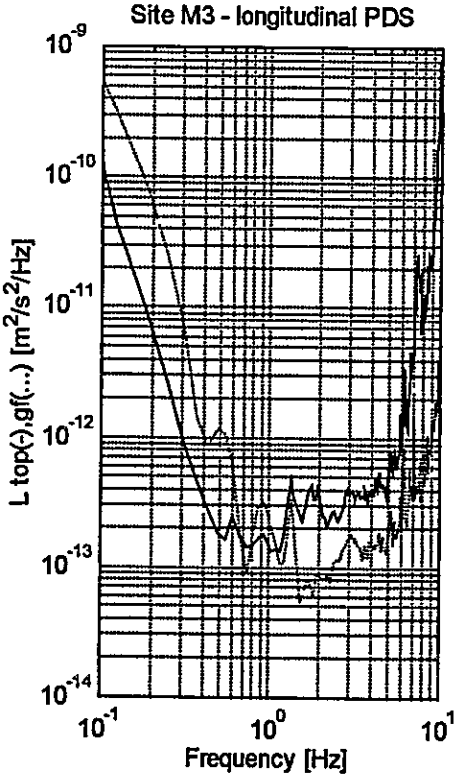

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

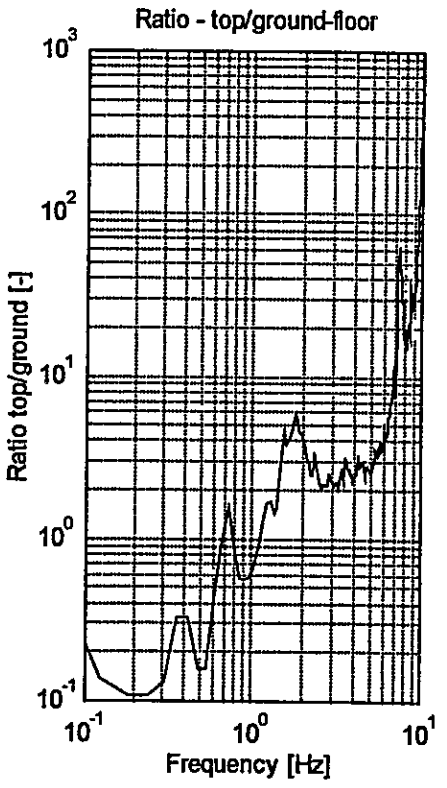

Site M2 - top particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

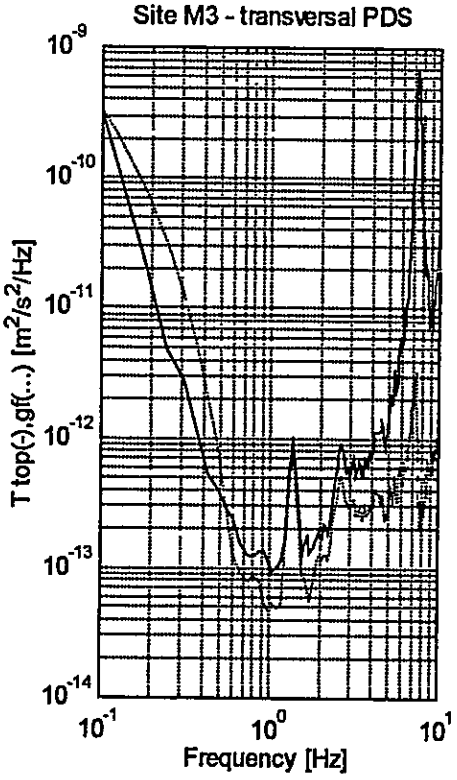
5.3.x Site M3 - Spectral data, spectral ratio, and particle motion

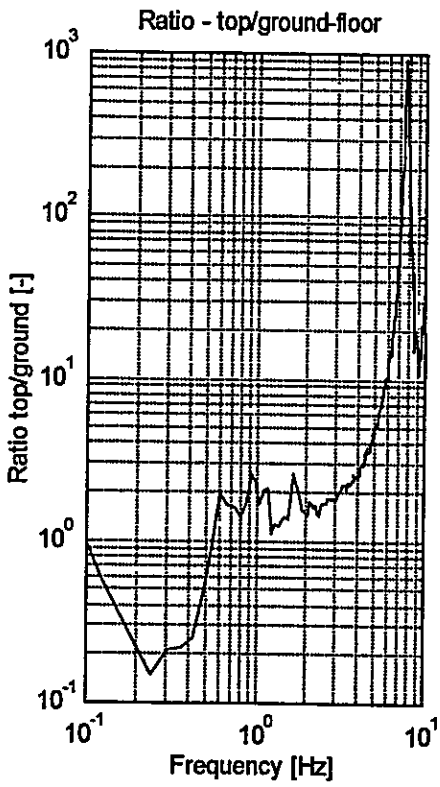


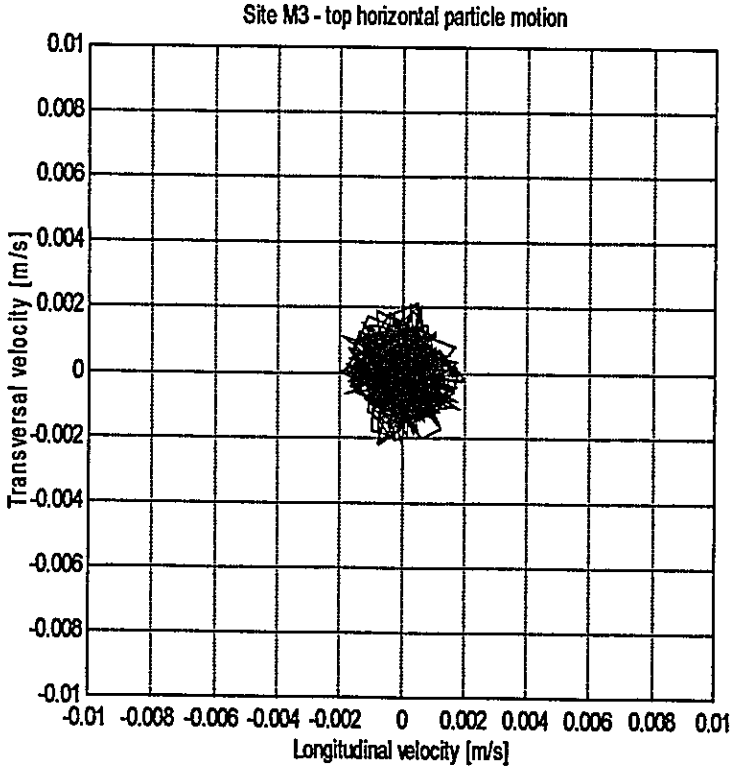




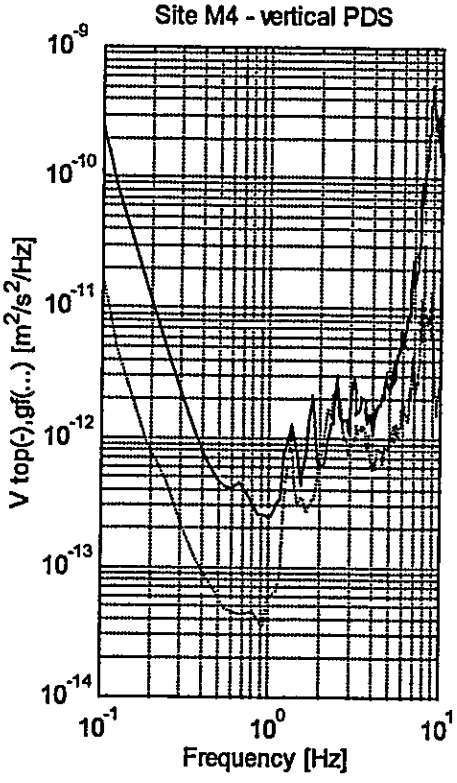


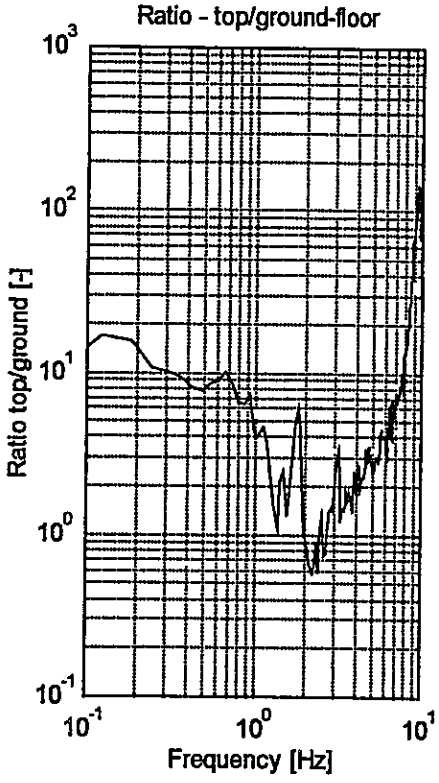

Site M3 - transversal PDS
T top(·),gf(...) [m²/s²/Hz]
Frequency [Hz]

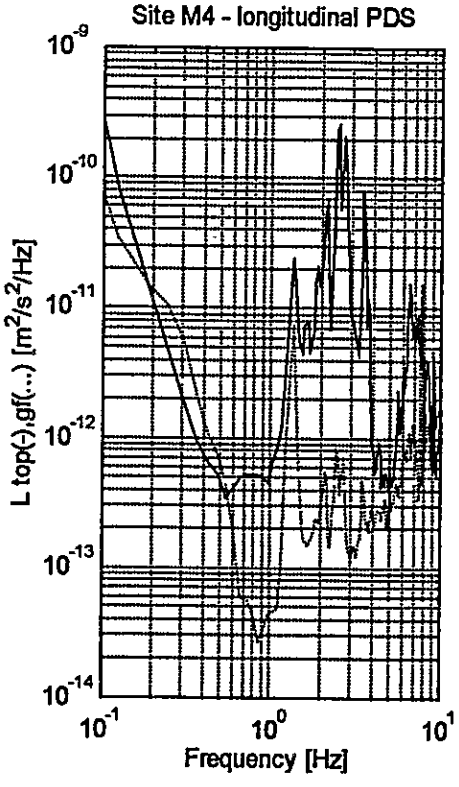

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

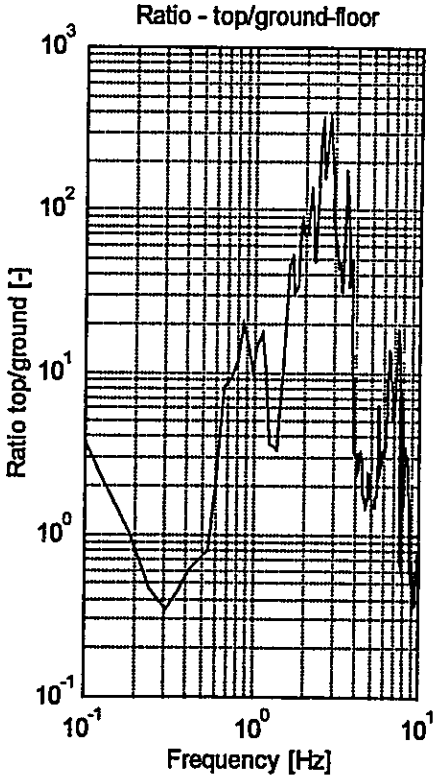

Site M3 - top horizontal particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

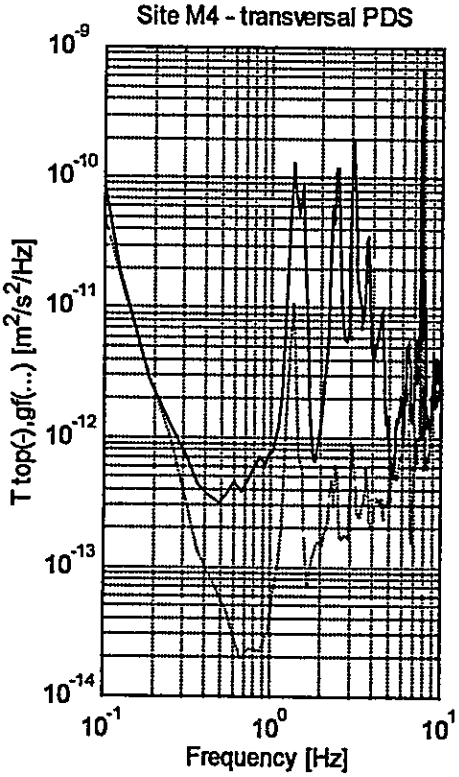
5.3.x Site M4 - Spectral data, spectral ratio, and particle motion

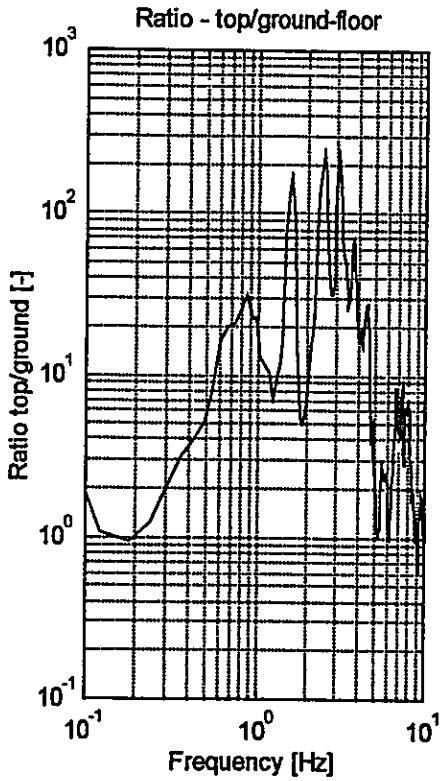


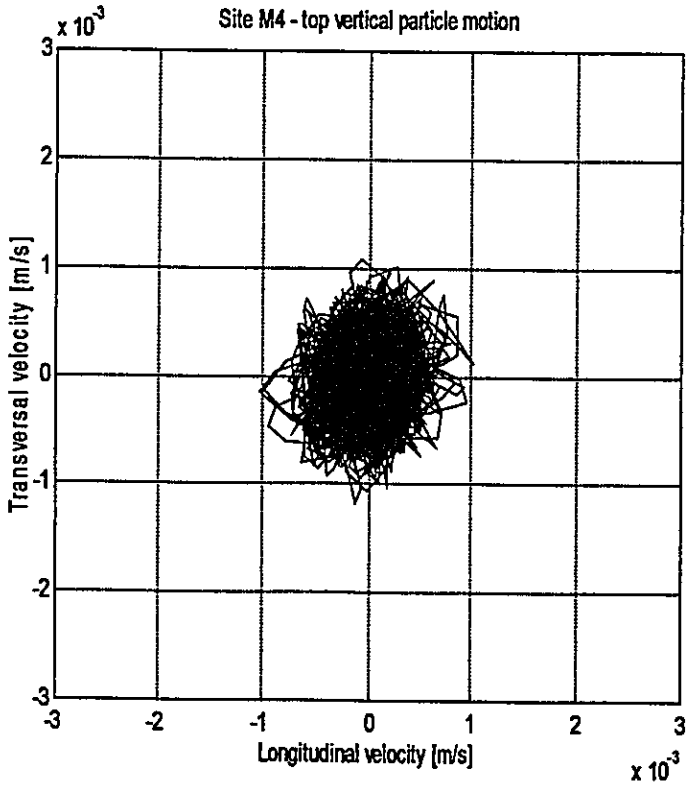




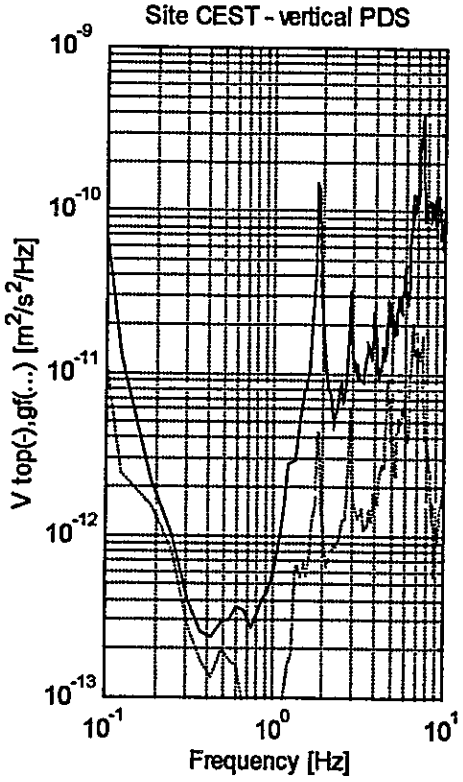


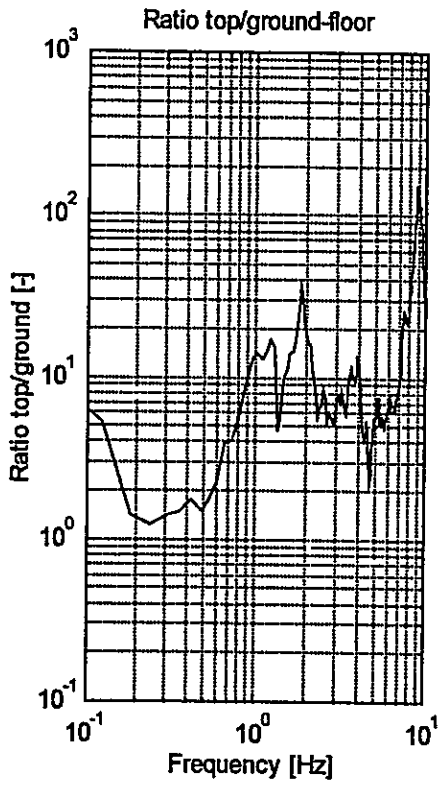

Site M4 - transversal PDS
T top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]

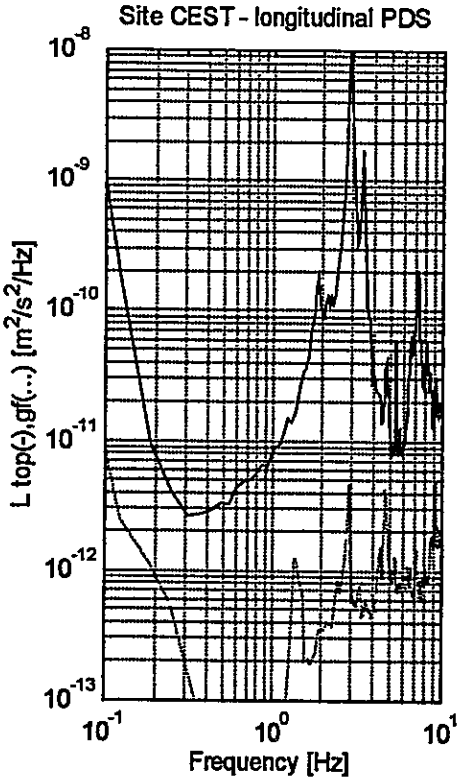

Ratio - top/ground-floor
Ratio top/ground [-]
Frequency [Hz]

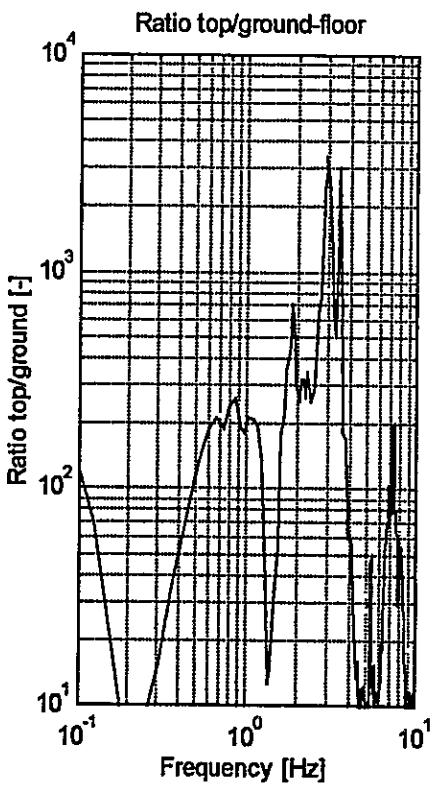

Site M4 - top vertical particle motion
x 10⁻³
Transversal velocity [m/s]
Longitudinal velocity [m/s]
x 10⁻³

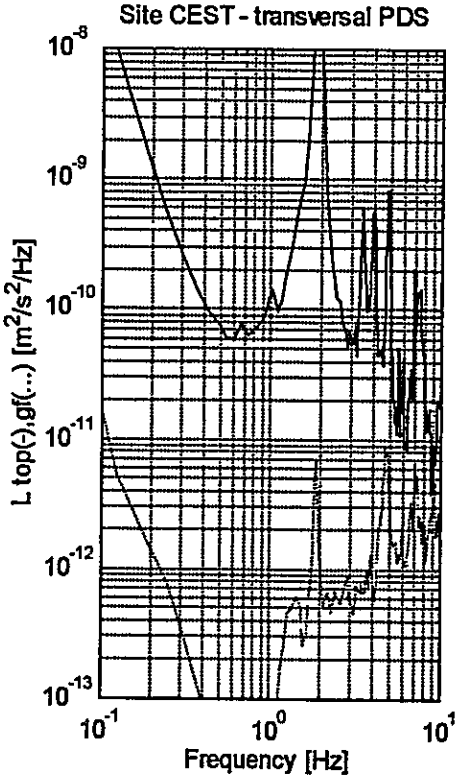
5.3.x Site CEST - Spectral data, spectral ratio, and particle motion

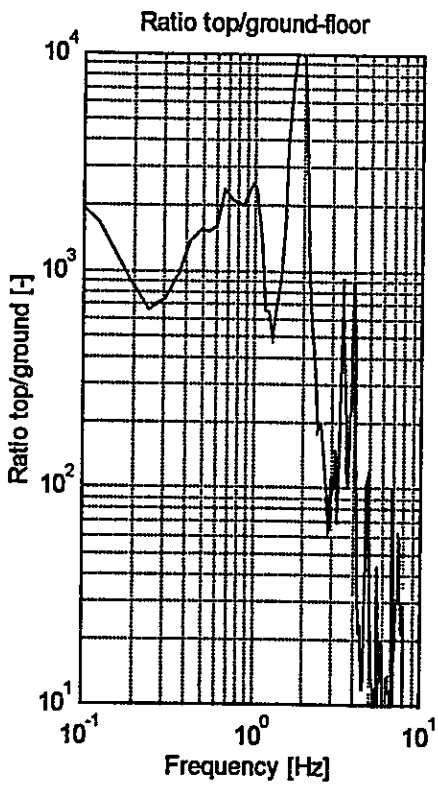


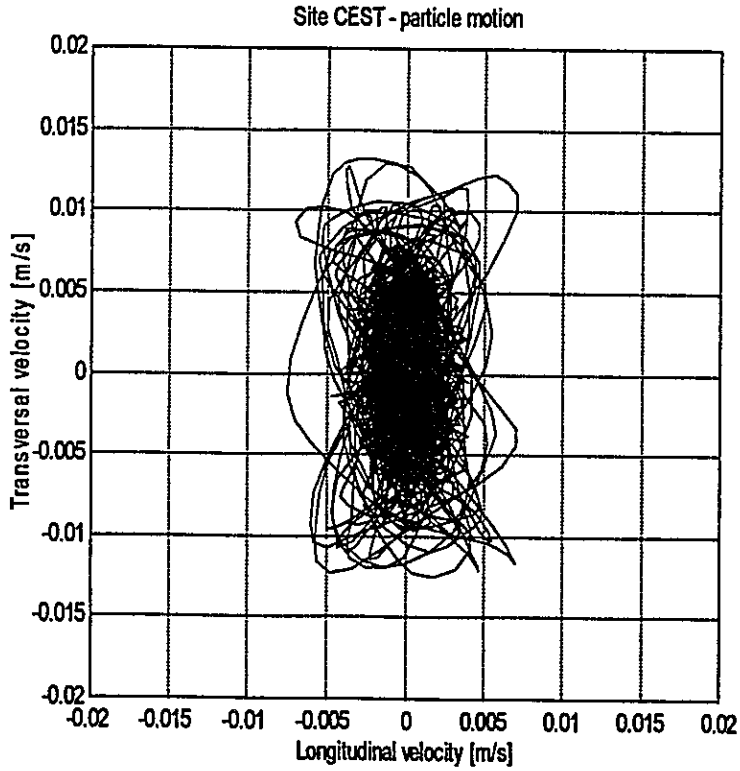







Site CEST - transversal PDS
L top(-),gf(...) [m²/s²/Hz]
Frequency [Hz]


Ratio top/ground-floor
Ratio top/ground [-]
Frequency [Hz]


Site CEST - particle motion
Transversal velocity [m/s]
Longitudinal velocity [m/s]

5.4 MatLab data processing details

5.4.1 General analysis procedure

Analysis procedure in form of MatLab command is given below. Custom made MatLab m functions (p2V.m, p2l.m, p2t.m, p2sV.m, ps2l.m, ps2t.m, srv.m, srl.m, srt.m, cpv.m, pm.m, decim.m) used in the procedure are explained in details in the next chapter. Comments inserted into the procedure are in italic font. Text in smaller characters is MatLab's output text.

```
To get started, type one of these commands: helpwin, helpdesk, or demo

% Defining path for custom made 'm' functions. Use your own mypath 'm' function.

» mypath

% Loading, displaying, editing, and saving edited vertical data (first measurement).Custom made 'm'
function 'p2V' is use for raw and edited data and 'p2sV' for zoomed data display. 'p2V' has an another
function 'decim' embedded, which decimates data, but correctly displays peak vales of the signal.

» load c:\iran00\data\site_cest\cestm1ch1.001
» load c:\iran00\data\site_cest\cestm1ch2.002
» p2V(cestm1ch1,cestm1ch2)
» title('Site CEST - vertical - raw data')

» ecestm1ch1=[cestm1ch1(1:60000);cestm1ch1(80000:length(cestm1ch1))];
» ecestm1ch2=[cestm1ch2(1:60000);cestm1ch2(80000:length(cestm1ch2))];
» p2v(ecestm1ch1,ecestm1ch2)
» title('Site CEST - vertical - edited data')

» p2sV(ecestm1ch1,ecestm1ch2)
» title('Site CEST - vertical - zoomed data')

» save c:\iran00\temp\ecestm1ch1.dat ecestm1ch1 /ascii
» save c:\iran00\temp\ecestm1ch2.dat ecestm1ch2 /ascii

% Loading, displaying, editing, and saving longitudinal data (second measurement).Custom made 'm'
function 'p2L is use for raw and edited data and 'p2sL' for zoomed data display. 'p2L' has an another
function 'decim' embedded, which decimates data, but correctly displays peak vales of the signal..

» load c:\iran00\data\site_cest\cestm2ch1.001
» load c:\iran00\data\site_cest\cestm2ch2.002
» p2l(cestm2ch1,cestm2ch2)
» title('Site CEST - longitudinal - raw data')

» ecestm2ch1 =
[cestm2ch1(4000:20000);cestm2ch1(24000:52000);cestm2ch1(57000:length(cestm2ch1))];
» ecestm2ch2 =
[cestm2ch2(4000:20000);cestm2ch2(24000:52000);cestm2ch2(57000:length(cestm2ch2))];
» p2l(ecestm2ch1,ecestm2ch2)
» title('Site CEST - longitudinal - edited data')

» p2sl(ecestm2ch1,ecestm2ch2)
» title('Site CEST - longitudinal - zoomed data')

» save c:\iran00\temp\ecestm2ch1.dat ecestm2ch1 /ascii
» save c:\iran00\temp\ecestm2ch2.dat ecestm2ch2 /ascii
```

% Loading, displaying, editing, and saving edited transversal data (third measurement).Custom made 'm' function 'p2T is use for raw and edited data and 'p2sT' for zoomed data display. 'p2T' has an another function 'decim' embedded, which decimates data, but correctly displays peak vales of the signal.

```
» load c:\iran00\data\site_cest\cestm3ch1.001
» load c:\iran00\data\site_cest\cestm3ch3.003
» p2t(cestm3ch1,cestm3ch3)
» title('Site CEST - transversal - raw data')

» ecestm3ch1=[cestm3ch1(4000:13000);cestm3ch1(17000:28000);cestm3ch1(44000:67000)];
» ecestm3ch3=[cestm3ch3(4000:13000);cestm3ch3(17000:28000);cestm3ch3(44000:67000)];
» p2t(ecestm3ch1,ecestm3ch3)
» title('Site CEST - transversal - edited data')

» p2st(ecestm3ch1,ecestm3ch3);
» title('Site CEST - transversal - zoomed data')

» save c:\iran00\temp\ecestm3ch1.dat ecestm3ch1 /ascii
» save c:\iran00\temp\ecestm3ch3.dat ecestm3ch3 /ascii
```

% Calculation of spectral information from edited data and spectral ratio of vertical signals. Custom made 'm' function 'srv' plots spectral and ratio graphs side by side. It uses two other 'm' functions. 'cpV' calculates and displays instrument corrected signal spectra of both data channels, function 'ratio' calculates and displays ratio of both spectra.

```
» [scestvg,scestvt,rcestv]=srv(ecestm1ch1,ecestm1ch2);

Warning: Divide by zero.
> In c:\iran00\programs\mfiles\cpv.m at line 39
  In c:\iran00\programs\mfiles\srv.m at line 8

Warning: Divide by zero.
> In c:\iran00\programs\mfiles\cpv.m at line 44
  In c:\iran00\programs\mfiles\srv.m at line 8
```

% These error messages are normal and are due to zero frequency at the far left of spectra.
% Coordinate axes and titles are adjusted and generated manually.

```
» subplot(121)
» axis([.1 10 1e-13 1e-9])
» title('Site CEST - vertical')
» subplot(122)
» title('Ratio top/ground-floor')
» subplot(121)
» title('Site CEST - vertical PDS')
```

% Saving vertical spectral and ratio data.

```
» save c:\iran00\temp\scestvg.dat scestvg /ascii
» save c:\iran00\temp\scestvt.dat scestvt /ascii
» save c:\iran00\temp\rcestv.dat rcestv /ascii
```

% Calculation of spectral information from edited data and spectral ratio of longitudinal signals. Custom made 'm' function 'srl' plots spectral and ratio graphs side by side. It uses two other 'm'

functions. 'cpL' calculates and displays instrument corrected signal spectra of both data channels, function 'ratio' calculates and displays ratio of both spectra.

```
» [scestlg,scestlt,rcestl]=srl(ecestm2ch1,ecestm2ch2);

Warning: Divide by zero.
> In c:\iran00\programs\mfiles\cpl.m at line 39
  In c:\iran00\programs\mfiles\srl.m at line 8

Warning: Divide by zero.
> In c:\iran00\programs\mfiles\cpl.m at line 44
  In c:\iran00\programs\mfiles\srl.m at line 8
```

% These error messages are normal and are due to zero frequency at the far left side of spectra.
% Coordinate axes and titles are adjusted and generated manually.

```
» subplot(121)
» axis([.1 10 1e-13 1e-8])
» title('Site CEST - longitudinal PDS')
» subplot(122)
» axis([.1 10 1e1 1e4])
» title('Ratio top/ground-floor')
```
% Saving longitudinal spectral and ratio data.

```
» save c:\iran00\temp\scestlg.dat scestlg /ascii
» save c:\iran00\temp\scestlt.dat scestlt /ascii
» save c:\iran00\temp\rcestl.dat rcestl /ascii
```

% Calculation of spectral information from edited data and spectral ratio of transversal signals. . Custom made 'm' function 'srt' plots spectral and ratio graphs side by side. It uses two other 'm' functions. 'cpT' calculates and displays instrument corrected signal spectra of both data channels, function 'ratio' calculates and displays ratio of both spectra.

```
» [scesttg,scesttt,rcestt]=srl(ecestm3ch1,ecestm3ch3);

Warning: Divide by zero.
> In c:\iran00\programs\mfiles\cpl.m at line 39
  In c:\iran00\programs\mfiles\srl.m at line 8

Warning: Divide by zero.
> In c:\uran00\programs\mfiles\cpl.m at line 44
  In c:\iran00\programs\mfiles\srl.m at line 8
```

% These error messages are normal and are due to zero frequency at the far-left side of spectra.
% Coordinate axes and titles are adjusted and generated manually.

```
» subplot(121)
» axis([.1 10 1e-13 1e-8])
» title('Site CEST - transversal PDS')
» subplot(122)
» title('Ratio top/ground-floor')
» subplot(122)
» axis([.1 10 1e1 1e4])
```

% Saving transversal spectral and ratio data.

```
» save c:\iran00\temp\scesttg.dat scesttg /ascii
» save c:\iran00\temp\scesttt.dat scesttt /ascii
» save c:\iran00\temp\rcestt.dat rcestt /ascii
```

% Loading second channel (longitudinal, top of the building) of third measurement, needed for particle motion calculation

» load c:\iran00\data\site_cest\cestm3ch2.002
% Returning plot mode to single frame mode and plotting particle motion using 'pm' custom made 'm' function.

» subplot
» pm(cestm3ch2,cestm3ch3)
» axis([-.02 .02 -.02 .02])
» title('Site

5.4.2 PSD.m function

Description of MatLab PSD.m function is taken from MatLab's on line help.

PSD Power Spectral Density estimate.

Pxx = PSD(X,NFFT,Fs,WINDOW) estimates the Power Spectral Density of signal vector X using Welch's averaged periodogram method. X is divided into overlapping sections, each of which is detrended, then windowed by the WINDOW parameter, then zero-padded to length NFFT. The magnitude squared of the length NFFT DFTs of the sections are averaged to form Pxx. Pxx is length NFFT/2+1 for NFFT even, (NFFT+1)/2 for NFFT odd, or NFFT if the signal X is complex. If you specify a scalar for WINDOW, a Hanning window of that length is used. Fs is the sampling frequency which doesn't effect the spectrum estimate but is used for scaling of plots.

[Pxx,F] = PSD(X,NFFT,Fs,WINDOW,NOVERLAP) returns a vector of frequencies the same size as Pxx at which the PSD is estimated, and overlaps the sections of X by NOVERLAP samples.

[Pxx, Pxxc, F] = PSD(X,NFFT,Fs,WINDOW,NOVERLAP,P) where P is a scalar between 0 and 1, returns the P*100% confidence interval for Pxx.

PSD(X,...,DFLAG), where DFLAG can be 'linear', 'mean' or 'none', specifies a detrending mode for the prewindowed sections of X. DFLAG can take the place of any parameter in the parameter list (besides X) as long as it is last, e.g. PSD(X,'mean');

PSD with no output arguments plots the PSD in the current figure window, with confidence intervals if you provide the P parameter.

The default values for the parameters are NFFT = 256 (or LENGTH(X), whichever is smaller), NOVERLAP = 0, WINDOW = HANNING(NFFT), Fs = 2, P = .95, and DFLAG = 'none'. You can obtain a default parameter by leaving it off or inserting an empty matrix [], e.g. PSD(X,[],10000).

5.4.3 Custom made MatLab .m functions

(1) Plotting two channel raw and edited data – function p2(x).m

Three m functions are used for plotting two channel time series data. p2v.m is used to plot vertical data, p2l.m is used to plot longitudinal data, and p2t.m is used to plot transversal data. The functions are identical apart of labelling ordinate axes of the graphs.

```
function y=p2V(a,b)

% Function 'p2V' plots two-channel,
% decimated (due to WORD limitations) signal in [m/s].
% Signals are not instrument TF corrected and not
% transformed to velocity units. Abscissa
% is in semples to facilitate data editing. Input variables
% must follow vertical ground-floor/vertica top.
% It is assumed that decimation searches for min and max
% values in 100 sample blocks (1.6 sec of signal at 62.5 Hz
% sampling.)

aa=decim(a);
la=length(aa);
samples=[1:la];
subplot(2,1,1)
plot(samples*50,aa)
ylabel('Vertical-ground floor [V]')
grid

bb=decim(b);
subplot(2,1,2)
plot(samples*50,bb)
ylabel('Vertical top [V]')
grid
xlabel('Samples [-]')

subplot(2,1,1)
% Type the title now
```

```
function y=p2L(a,b)

% Function 'p2L' plots two-channel,
% decimated (due to WORD limitations) signal in [V].
% Signals are not instrument TF corrected and not
% transformed to velocity units. Abscissa
% is in samples to facilitate data editing. Input variables
% must follow L ground-floor/L top.
% It is assumed that decimation searches for min and max
% values in 100 sample blocks (1.6 sec of signal at 62.5 Hz
% sampling.)

aa=decim(a);
la=length(aa);
samples=[1:la];
subplot(2,1,1)
plot(samples*50,aa)
ylabel('L ground-floor [V]')
grid

bb=decim(b);
subplot(2,1,2)
plot(samples*50,bb)
ylabel('L top [V]')
grid
```

```
xlabel('Samples [-]')

subplot(2,1,1)
% Type the title now
```

```
function y=p2V(a,b)



% Function 'p2V' plots two-channel,
% decimated (due to WORD limitations) signal in [m/s].
% Signals are not instrument TF corrected and not
% transformed to velocity units. Abscissa
% is in samples to facilitate data editing. Input variables
% must follow vertical ground-floor/vertical top.
% It is assumed that decimation searches for min and max
% values in 100 sample blocks (1.6 sec of signal at 62.5 Hz
% sampling.)

aa=decim(a);
la=length(aa);
samples=[1:la];
subplot(2,1,1)
plot(samples*50,aa)
ylabel('Vertical-ground floor [V]')
grid

bb=decim(b);
subplot(2,1,2)
plot(samples*50,bb)
ylabel('Vertical top [V]')
grid
xlabel('Samples [-]')
subplot(2,1,1)
% Type the title now
```

(2) Plotting two channel zoomed data – function ps2(x).m

Three m functions are used for plotting two channel zoomed time series data. ps2v.m is used to plot vertical data, p2sl.m is used to plot longitudinal data, and p2st.m is used to plot transversal data. 10 seconds of time series is displayed at 62.6 Hz sampled data. The functions are identical apart of labelling ordinate axes of the graphs.

```
function y=p2sV(a,b)



% Function p2sV plots 625 points of two time series.

% Vertical signals must be inputted.
% It assumes 62.5 Hz sampling, so the duration of
% displayed record is 10 seconds.
% Function is used to display two channel seismic
% records. Input signals must follow vertical-ground
% floor/vertical top.

t=0:0.016:10;

subplot(211)
plot(t,a(1:626))
grid
ylabel('Vertical-ground floor [V]')
```

```
subplot(212)
plot(t,b(1:626))
grid
ylabel('Vertical - top [V]')
xlabel('Time [s]')
subplot(211)
```

```
function y=p2sL(a,b)


% Function p2sL plots 625 points of two time series.

% It assumes 62.5 Hz sampling, so the duration of

% displayed record is 10 seconds.

% Function is used to display two channel zoomed seismic
% records. Input signals must follow L ground
% floor/L top.

t=0:0.016:10;

subplot(211)
plot(t,a(1:626))
grid
ylabel('Long.- ground floor [V]')

subplot(212)
plot(t,b(1:626))
grid
ylabel('Longitudinal - top [V]')
xlabel('Time [s]')
subplot(211)
```

```
function y=p2sT(a,b)


% Function p2sT plots 625 points of two time series.

% It assumes 62.5 Hz sampling, so the duration of

% displayed record is 10 seconds.
% Function is used to display two channel seismic
% records. Input signals must follow T ground
% floor/T top.

t=0:0.016:10;

subplot(211)
plot(t,a(1:626))
grid
ylabel('Trans.- ground floor [V]')

subplot(212)
plot(t,b(1:626))
grid
ylabel('Transversal - top [V]')
xlabel('Time [s]')
subplot(211)
```

(3) Plotting spectra and spectra ratio of two channel data – function sr(x).m

Three m functions are used for calculation, outputting, and plotting of instrument corrected spectra and spectral ratio of two channel time series data. Spectra of both channels are displayed on the left graph, spectral ratio is displayed on the right graph. Calculation of spectra is done by imbedded m function cpv.m (cpl.m, cpt,m) and calculation of the ratio is performed by an imbedded m function ratio.m. Function srv.m is used to display vertical data, srl.m is used to display longitudinal data, and srt.m is used to manage transversal data. The functions are identical apart of labelling ordinate axes of the graphs.

```
function [vg,vt,vr]=srv(svg,svt)


% Function sr calculates, outputs, and plots vertical

% ground and top PDSs and corresponding spectral

% ratio.


subplot(121)

[vg,vt,f]=cpv(svg,svt);

subplot(122)

vr=ratio(vg,vt);
```

```
function [lg,lt,lr]=srl(slg,slt)


% Function srl calculates, outputs, and plots longitudinal

% ground-floor and top PDSs and corresponding spectral

% ratio.


subplot(121)

[lg,lt,f]=cpl(slg,slt);

subplot(122)

lr=ratio(lg,lt);
```

```
function [tg,tt,tr]=srt(stg,stt)


% Function sr calculates, outputs, and plots

% transversal ground and top PDSs and

% corresponding spectral ratio.
```

```
subplot(121)

[tg,tt,f]=cpt(stg,stt);

subplot(122)

tr=ratio(tg,tt);
```

(4) Calculation of PDSs of two channel time series data – function cp(x).m

Functions cpv.m, cpl,m, and cpt,m return two spectra calculated from two vertical (longitudinal, transversal) input time series. MatLab PDS.m is used for spectra calculation. Spectra are instrument corrected.

```
function [a,b,f]=cpv(xx,yy)


% Function 'cpv' calculates instrument corrected PDSs of vertical

% ground floor and top components using MatLab psd.m function;

% xx is vertical ground floor time series data in [V],
% yy is vertical top building time series data in [V],
% f0 are corresponding resonant frequencies of SP seismometers in [Hz],
% ceta are seismometers' relative damping, Gl are loaded
% generator constant in [Vs/m].
% psdx and psdy are not yet instrument corrected PSDs;
% 62.5 Hs sampling frequency is assumed, 1024 point data
% ensembles are used with 25% overlapping. Hanning weighting window is
% applied, and linear detrending of data windows is used.
% a and b are corresponding instrument corrected PDSs.
% f is frequency of PDS points.
% Spectral division method is used for instrument correction.
% Spectra are multiplied by square value of the amplitude of
% inverse transfer functions of seismometers. SP
% seismometers are modeled as a second order dynamic system with
% f0 resonant frequency and 'ceta' relative damping.
% PDSs are plotted in a single graph in loglog scale.
% This function assumes vertical orientation of sensors and
% that seismometer SS-1 SN2004 is used on
% ground floor level and seismometer SS-1 SN2006 on top of
% the building.

f0x=1.045;
cetax=0.64;
Glx=157;

f0y=1.02;
cetay=0.70;
Gly=154.2;

x=xx./Glx;
[psdx,f]=psd(x,1024,62.5,[],256,'linear');
omega0x=2*pi*f0x;
omega=2*pi*f;
a=(abs((omega0x.^2+2*omega0x*cetax*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdx;

y=yy./Gly;
[psdy,f]=psd(y,1024,62.5,[],256,'linear');
omega0y=2*pi*f0y;
```

```
b=(abs((omega0y.^2+2*omega0y*cetay*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdy;

loglog(f,a,'k:',f,b,'k-')
axis([0.1 10 1e-12 1e-7])
grid
ylabel('V top(-),gf(...) [m^2/s^2/Hz]')
xlabel('Frequency [Hz]')
```

```
function [a,b,f]=cpl(xx,yy)


% Function cpL calculates instrument corrected PDSs of longitudinal

% ground floor and top components using MatLab psd.m function;
% xx is longitudinal ground floor time series data in [V],
% yy is longitudinal top building time series data in [V],
% f0 are corresponding resonant frequencies of SP seismometers in [Hz],
% ceta are seismometers' relative damping, Gl are loaded
% generator constant in [Vs/m].
% psdx and psdy are not yet instrument corrected PSDs;
% 62.5 Hs sampling frequency is assumed, 1024 point data
% ensembles are used with 25% overlapping. Hanning weighting window is
% applied, and linear detrending of data windows is used.
% a and b are corresponding instrument corrected PDSs.
% f is frequency of PDS plots.
% Spectral division method is used for instrument correction.
% Spectra are multiplied by square value of the amplitude of
% inverse transfer functions of seismometers. SP
% seismometers are modeled as a second order dynamic system with
% f0 resonant frequency and 'ceta' relative damping.
% PDSs are plotted in a single graph in loglog scale.
% This function assumes longitudinal orientation of sensors and
% that seismometer SS-1 SN2004 is used on
% ground floor level and seismometer SS-1 SN2006 on top of
% the building.

f0x=1.045;
cetax=0.64;
Glx=157;

f0y=1.02;
cetay=0.70;
Gly=154.2;

x=xx./Glx;
[psdx,f]=psd(x,1024,62.5,[],256,'linear');
omega0x=2*pi*f0x;
omega=2*pi*f;
a=(abs((omega0x.^2+2*omega0x*cetax*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdx;

y=yy./Gly;
[psdy,f]=psd(y,1024,62.5,[],256,'linear');
omega0y=2*pi*f0y;
b=(abs((omega0y.^2+2*omega0y*cetay*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdy;

loglog(f,a,'k:',f,b,'k-')
axis([0.1 10 1e-12 1e-7])
grid
ylabel('L top(-),gf(...) [m^2/s^2/Hz]')
```

```
xlabel('Frequency [Hz]')
```

```
function [a,b,f]=cpt(xx,yy)

% Function cpt calculates instrument corrected PDSs of transversal
% ground floor and top components using MatLab psd.m function;
% xx is transversal ground floor time series data in [V],
% yy is transversal top building time series data in [V],
% f0 are corresponding resonant frequencies of SP seismometers in [Hz],
% ceta are seismometers' relative damping, Gl are loaded
% generator constant in [Vs/m].
% psdx and psdy are not yet instrument corrected PSDs;
% 62.5 Hs sampling frequency is assumed, 1024 point data
% ensembles are used with 25% overlapping. Hanning weighting window is
% applied, and linear detrending of data windows is used.
% a and b are corresponding instrument corrected PDSs.
% f is frequency of PDS plots.
% Spectral division method is used for instrument correction.
% Spectra are multiplied by square value of the amplitude of
% inverse transfer functions of seismometers. SP
% seismometers are modeled as a second order dynamic system with
% f0 resonant frequency and 'ceta' relative damping.
% PDSs are plotted in a single graph in loglog scale.
% This function assumes transversal orientation of sensors and
% that seismometer SS-1 SN2004 is used on
% ground floor level and seismometer SS-1 SN2511 on top of
% the building.

f0x=1.045;
cetax=0.64;
Glx=157;

f0y=0.965;
cetay=0.75;
Gly=158.7;

x=xx./Glx;
[psdx,f]=psd(x,1024,62.5,[],256,'linear');
omega0x=2*pi*f0x;
omega=2*pi*f;
a=(abs((omega0x.^2+2*omega0x*cetax*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdx;

y=yy./Gly;
[psdy,f]=psd(y,1024,62.5,[],256,'linear');
omega0y=2*pi*f0y;
b=(abs((omega0y.^2+2*omega0y*cetay*omega*j+(omega*j).^2)./(omega*j).^2)).^2
.*psdy;

loglog(f,a,'k:',f,b,'k-')
axis([0.1 10 1e-12 1e-7])
grid
ylabel('T top(-),gf(...) [m^2/s^2/Hz]')
xlabel('Frequency [Hz]')
```

(5) Calculation and plotting of ratio of two PDS data – function ratio.m

Function ratio.m calculates and plots ratio of two input spectral data. Loglog scale is used for abscissa and ordinate.

```
function y=ratio(a,b)
```

```
% Function ratio calculates and plots ratio

% of top spectra to ground floor spectra.


f=0:31.25/512:31.25;

y=b./a;

loglog(f,y,'k-')

xlabel('Frequency [Hz]')

ylabel('Ratio top/ground [-]')

axis([0.1 10 .1 1000])
```

(6) Decimation of data for display purposes and printing within MS Word.

Number of point processed in Matlab is practically unlimited. However, exporting graphic results (graphs) from MatLab to MS word is limited. Therefore we need to decimate time series data. For proper display of decimated data function decim.m is used. It decimates data 1:50, but keeps the information about peak values in every 50-point data block preserved. This property guaranties correct editing of raw data, since all peaks in data are preserved.

```
function y=decim(x)


% Function 'decim' decimates seismic data to allow

% screen display and print of time series with proper peak values

% and importing graphs to MS WORD. If time series are too long

% WORD doesn't import graphs correctly. Therefore data must be
% decimated. To keep peak information correct, 'decim' function
% is used.
% 62.5 Hz data are decimated 1:50. In each data block max and
% min values are searched for and are taken as new data points.
% Function should be used for display and print purposes ONLY!
% x is input time series, y is decimated output.

ml=length(x);
ns=fix(ml/100);
for i=1:ns
      y(2*i-1)=max(x(((i-1)*100+1):((i-1)*100+100)));
      y(2*i)=min(x(((i-1)*100+1):((i-1)*100+100)));
end
```

5.5 Sensor technical specification

Short period seismometer Kinemetrics SS-1

Type of sensor: passive, moving coil
Natural period: 1 s nominal, factory adjustable from 0.5 to 2 Hz
Weight of moving mass: 1.45 kg
Mass travel: 2 mm
Coil resistance: 5000 nominal
Calibration coil resistance: 100
Open generator constant: 345 Vs/m nominal
Calibration coil generator constant: 0.4 N/A nominal
Housing: watertight case
Operating temperature: -40^0 to 70 ^{0}C
Size: 305 x 140 mm diameter
Weight: 5.0 kg

See http://www.kinemetrics.com for more detailed technical description.

5.6 Sensor calibration sheets

SS-1, S/N2004

Mass M	1.45 kg
Intrinsic relative damping h_m	0.1049
Natural frequency, Vertical orientation	0.986
Natural frequency, Horizontal orientation	0.980
Coil resistance, R_c	5644
Calibration coil resistance R_{cc}	100
Critical damping resistance	6309
External resistance, R_x for $h_t = 0.7$	4957
Open generator constant G_0	336 Vs/m
Date:	11/14/1991

SS-1, S/N2006

Mass M	1.45 kg
Intrinsic relative damping h_m	0.1057
Natural frequency, Vertical orientation	1.012
Natural frequency, Horizontal orientation	0.986
Coil resistance, R_c	5799
Calibration coil resistance R_{cc}	101
Critical damping resistance	6222
External resistance, R_x for $h_t = 0.7$	4670
Open generator constant G_0	338 Vs/m
Date:	11/14/1991

SS-1, S/N2511

Mass M	1.45 kg
Intrinsic relative damping h_m	0.103
Natural frequency, Vertical orientation	1.021
Natural frequency, Horizontal orientation	0.955
Coil resistance, R_c	5918
Calibration coil resistance R_{cc}	101
Critical damping resistance	6635
External resistance, R_x for $h_t = 0.7$	5235
Open generator constant G_0	352 Vs/m
Date:	09/09/1994

5.7 Data logger technical specifications

Kinemetrics SSR-1 Solid State Recorder

(1) Acquisition:

Number of channels: 3 (6 optionally)
Modes of operation: continuous, triggered, time windowed, manual recording
Channel skew: 30 s
Dynamic range: 16 bit
Bandwidth: DC to antialiasing filter
High-pass filter: 0.01 Hz
Antialiasing filters: 3 plug-in filters, 5, 15, 50 Hz, 6-pole Butterworth; other values optional; Bessel filters optional
Preamplifier gain: 1, 10 100, 1000 (0, 20, 40, 60 dB)
Full scale amplitude: +/- 2.5 V at 0 dB gain
Sensitivity: approximately LSB 0.076 V at60 dB gain
Noise: approximately 1 LSB RMS (0.1 to 10 Hz)

(2) Trigger

Band pass filtered Threshold trigger
STA/LTA (Ratio or Difference)
Manual trigger
Time windowed trigger
Voting scheme

(3) Storage

Pre-event memory: 0 – 40 s at 3 channels and 200 Hz sampling
Post-event memory: 1 to 65.000 scans
Recording medium: 1 Mbyte (optionally up to 4 Mbyte) of CMOS RAM
Play back: serial RS-232C link to PC; from 300 baud to 115 kbaud and optionally parallel port link

(4) Power equipment

Power supply: internal 12 V, 6.5 Ah battery; external power connector, 12 V
Current drain: 10 mA OFF, 140 mA ON (not triggered); higher when recording data

(5) Environment and physical characteristics

Operating Temperature: -20^0 to 65^0 C

Humidity: 100%
Dimensions: 23 x 41 x 43 cm
Weight: 17 kg

See http://www.kinemetrics.com for detailed technical description.

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