I76 Ambient Vibration Monitoring - Data Processing

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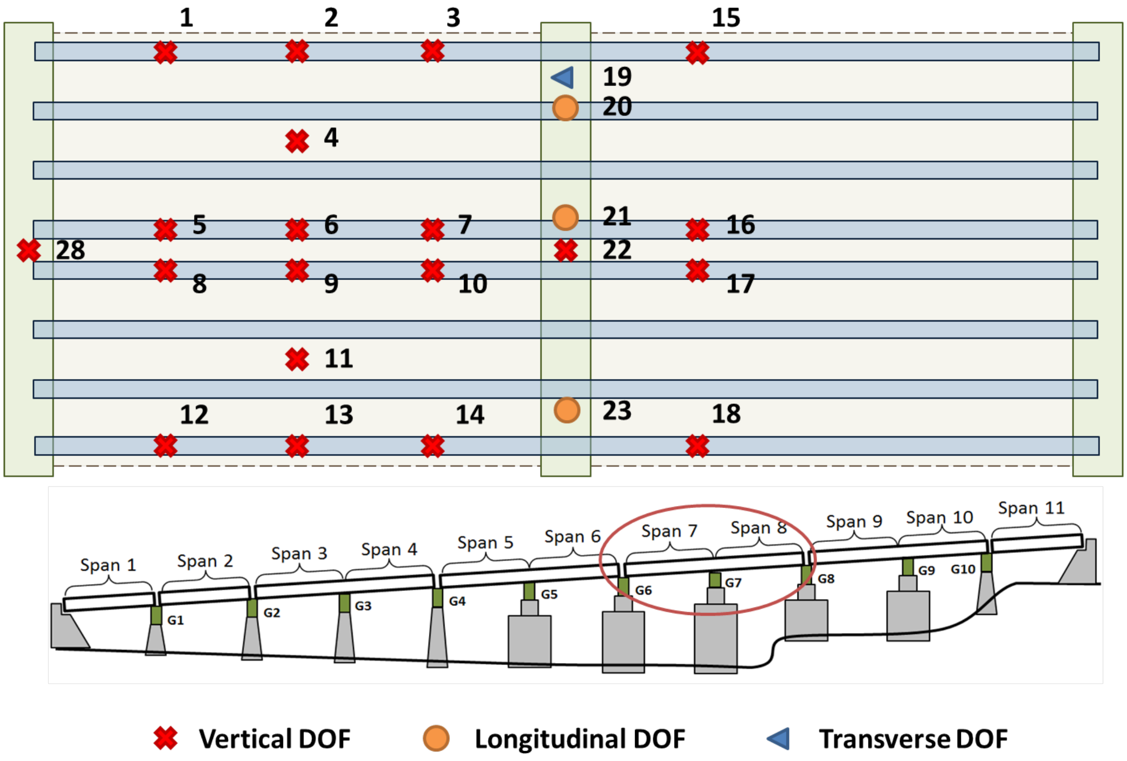
John DeVitis July 28th, 2016

vma fcns called: getrms getpsd getcpsd

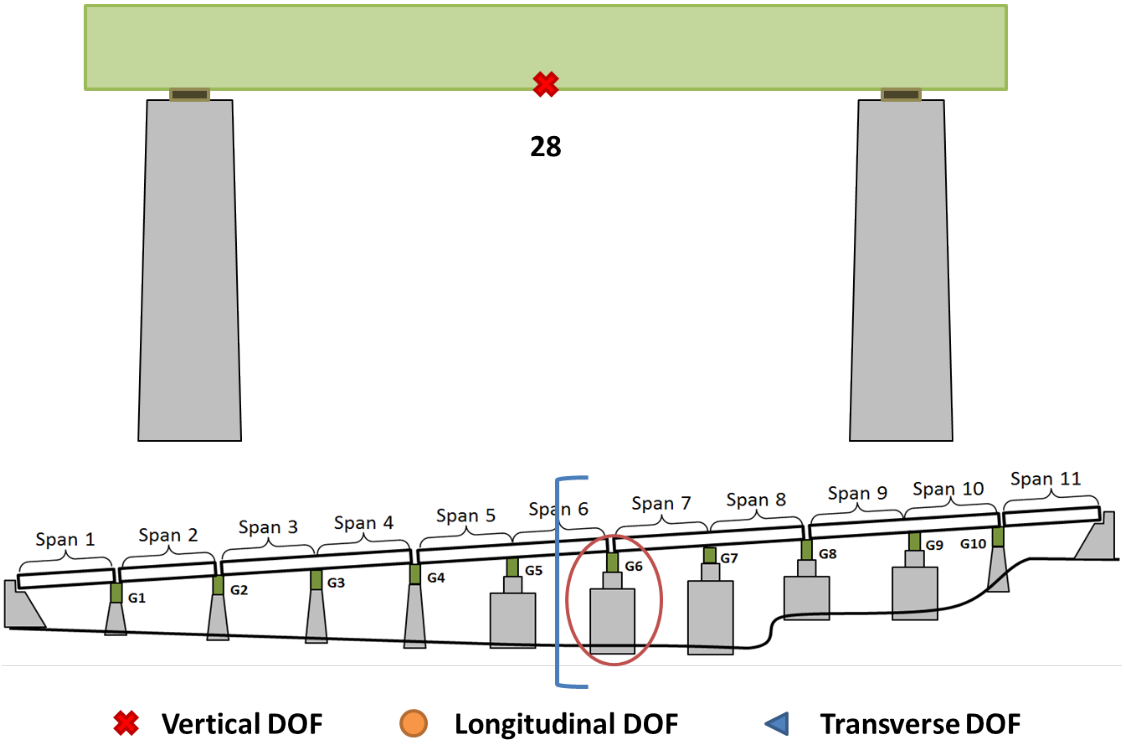
Superstructure Instrumentation Plan

Note the DOF call outs - they are also the channel numbers (column indices of the data array)

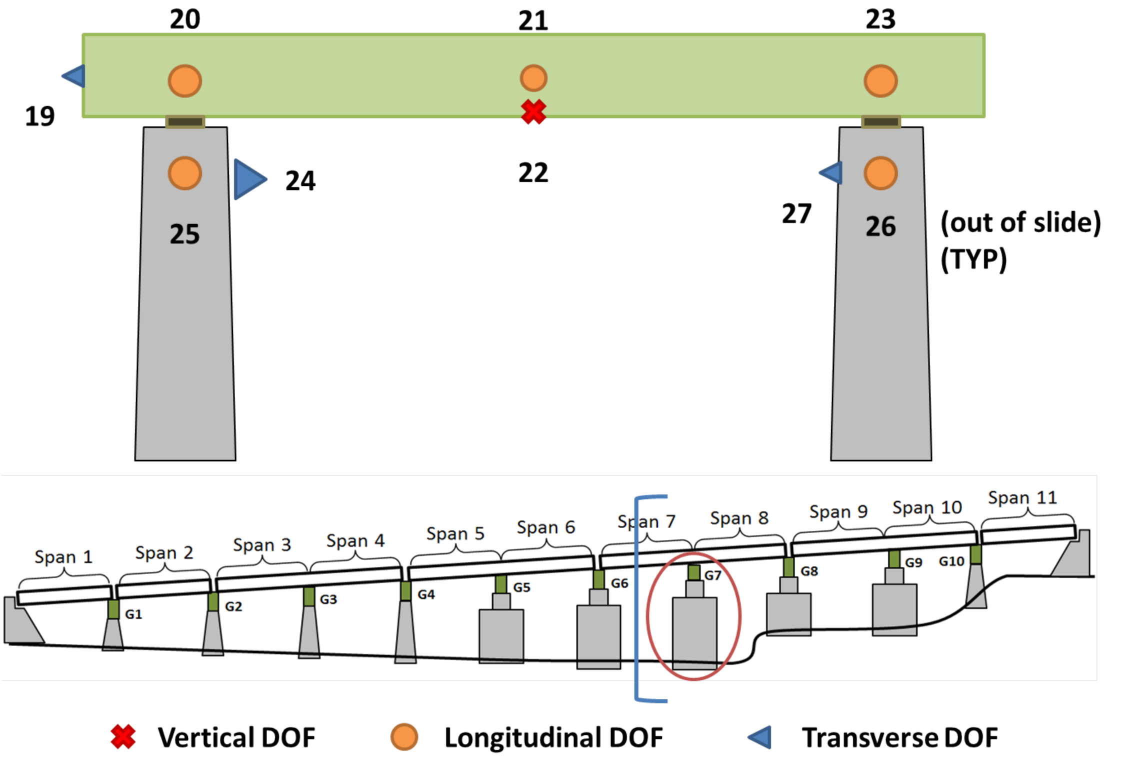


Substructure Instrumentation

Pier G6:


28
Span 1
Span 2
Span 3
Span 4
Span 5
Span 6
Span 7
Span 8
Span 9
Span 10
Span 11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
✖ Vertical DOF
● Longitudinal DOF
◀ Transverse DOF

Pier G7:


20
21
23
19
24
22
25
27
26
(out of slide)
(TYP)
Span 1
Span 2
Span 3
Span 4
Span 5
Span 6
Span 7
Span 8
Span 9
Span 10
Span 11
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
✖ Vertical DOF
● Longitudinal DOF
◀ Transverse DOF

Load data files

- Record starts at 1:16PM on July 27th, 2016
- Video began at ~1:45PM
- File names must be on Matlab's search path

```
% list of file names (absolute path of where data is stored)
fnames = {'C:\Users\John\Desktop\I76_data
\I76_07272016_ambient3.txt';...
          'C:\Users\John\Desktop\I76_data
\I76_07272016_ambient3_01.txt';...
          'C:\Users\John\Desktop\I76_data
\I76_07272016_ambient3_2.txt';...
          'C:\Users\John\Desktop\I76_data
\I76_07272016_ambient3_3.txt'};

% pre-allocate data array - empty due to unknown length
data = [];

% loop files to load
for ii = 1:length(fnames)
    dat = dlmread(fnames{ii});  % load data into temp array, dat
    data = [dat; data];         % concat new file to running list
end

% only keep first 28 channels (channels 29-32 not used)
data = data(:,1:28);
```

Sampling Info

Temporal sampling info

```
fs = 200;                       % sampling frequnecy [hz]
dt = 1/fs;                      % time step [seconds]
t = 0:dt:length(data)*dt-dt;    % form time vector [seconds]
tMins = t./60;                  % tim vector [minutes]
```

DOF Indices, Coordinates, & Labels

Indices for vertical, transverse, and longitudinal DOF with corresponding DOF coordinates

Notes:

- Indices are the respective column index for data array
- Strand7 model (0,0) starts at first right **interior** girder. These coordinates have the (0,0) starting at the first right **exterior** girder.

```
% vertical dof indices
dof.vert.super = 1:18;
dof.vert.sub   = [22 28];
dof.vert.all = [dof.vert.super dof.vert.sub];
```

```
% transverse dof indices
dof.trans.sub = [19 24 27];

% longitudinal dof indices
dof.long.super = [20 21 23];
dof.long.sub = [25 26];
dof.long.all = [dof.long.super dof.long.sub];

% index for all dof
dof.all = [dof.vert.all dof.trans.sub dof.long.all];

% build dof legend
leg = cell(1,length(dof.all));
for ii = 1:length(leg)
    leg{ii} = ['DOF: ' num2str(ii)];
end
dof.labels = leg; % assign to dof struct

%
% % grab general dimensions from model
% oneSpanLength = 136.5;  % ft
% oneSpanWidth = 67.3;    % ft
% oneGirderLine = [.25 .5 .75 1.25] * oneSpan;
```

Data Stats

- Root mean squared (RMS) for each DOF
- Find min and max RMS

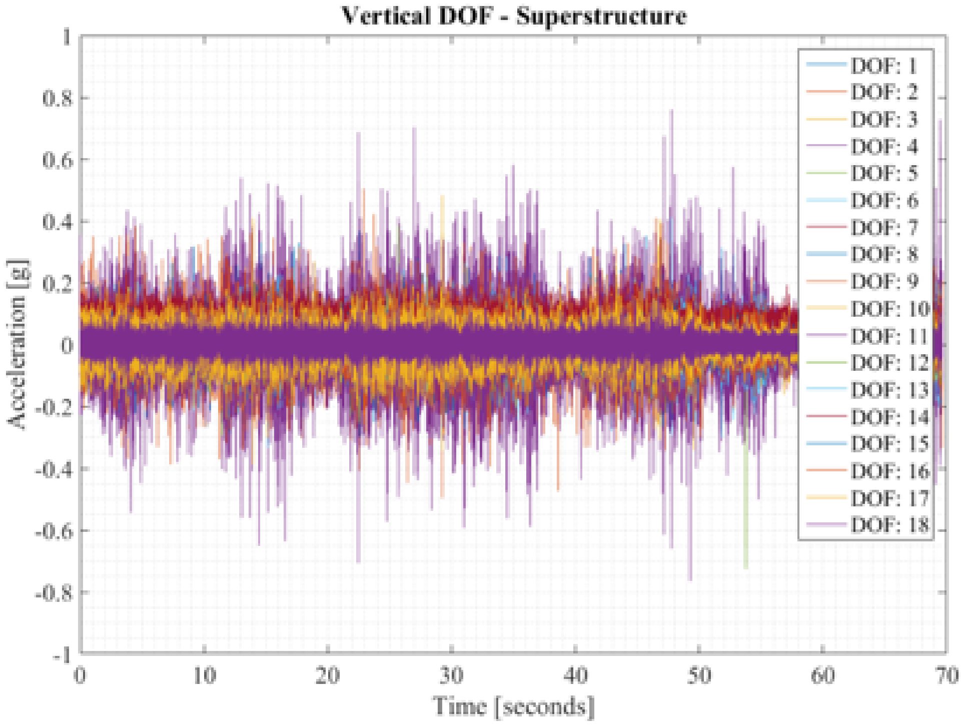
```
% get rms for each DOF
rmsRaw = getrms(data);
% loop to format
for ii = 1:size(data,2);
    rmsData{ii,1} = dof.labels{ii};
    rmsData{ii,2} = rmsRaw(ii);
end
% display
disp(rmsData);

% get rms stats & display
[Y,I] = min(rmsRaw);
fprintf('\n\nMinimum RMS - DOF %s - Value
 %s[g]\n',num2str(I),num2str(Y));

[Y,I] = max(rmsRaw);
fprintf('Minimum RMS - DOF %s - Value %s[g]\n',num2str(I),num2str(Y));
```

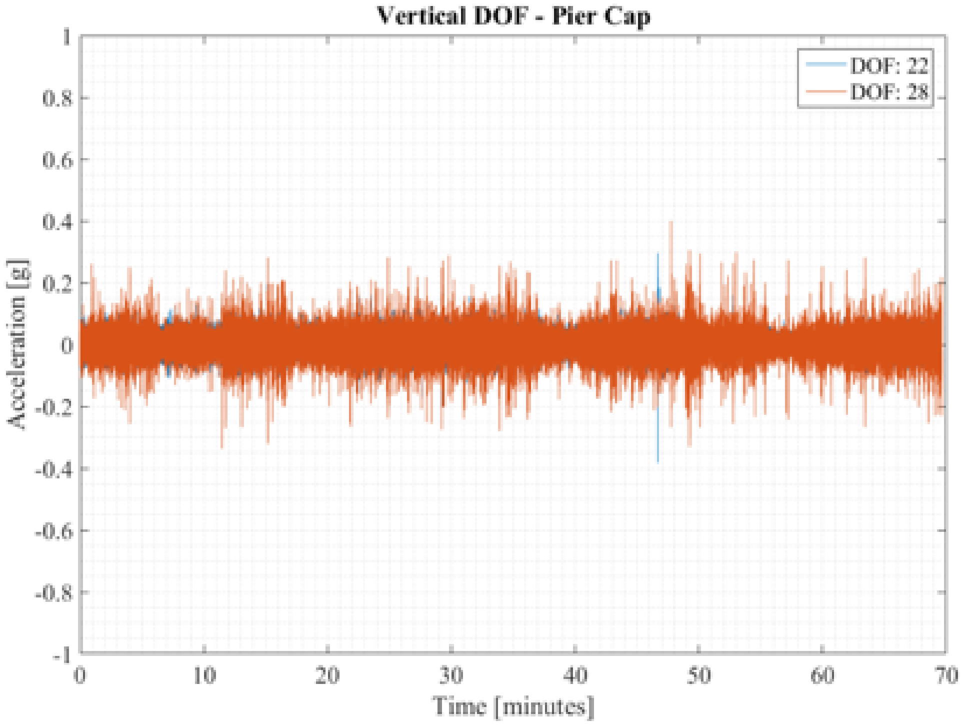
```
    'DOF: 1'     [0.0184]
    'DOF: 2'     [0.0240]
    'DOF: 3'     [0.0158]
    'DOF: 4'     [0.0556]
    'DOF: 5'     [0.0206]
    'DOF: 6'     [0.0340]
    'DOF: 7'     [0.0207]
    'DOF: 8'     [0.0271]
    'DOF: 9'     [0.0375]
    'DOF: 10'    [0.0289]
    'DOF: 11'    [0.0355]
    'DOF: 12'    [0.0185]
    'DOF: 13'    [0.0221]
    'DOF: 14'    [0.0467]
    'DOF: 15'    [0.0181]
    'DOF: 16'    [0.0209]
    'DOF: 17'    [0.0295]
    'DOF: 18'    [0.0188]
    'DOF: 19'    [0.0947]
    'DOF: 20'    [0.0109]
    'DOF: 21'    [0.0726]
    'DOF: 22'    [0.0239]
    'DOF: 23'    [0.0115]
    'DOF: 24'    [0.0016]
    'DOF: 25'    [0.0016]
    'DOF: 26'    [0.0026]
    'DOF: 27'    [0.0020]
    'DOF: 28'    [0.0312]


Minimum RMS - DOF 25 - Value 0.0015531[g]
Minimum RMS - DOF 19 - Value 0.094686[g]
```

Time Plots - Vertical DOF

```
% create figure w/ increased resolution (from default)
figWidth = 1120; % pixels
figHeight = 840;
rect = [0 50 figWidth figHeight];
figure('OuterPosition', rect)


% plot vertical superstructure
ind = dof.vert.super;
plot(tMins,data(:,ind));
title('Vertical DOF - Superstructure');
xlabel('Time [seconds]')
ylabel('Acceleration [g]')
ylim([-1 1])
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow

% plot vertical sub
ind = dof.vert.sub;
```

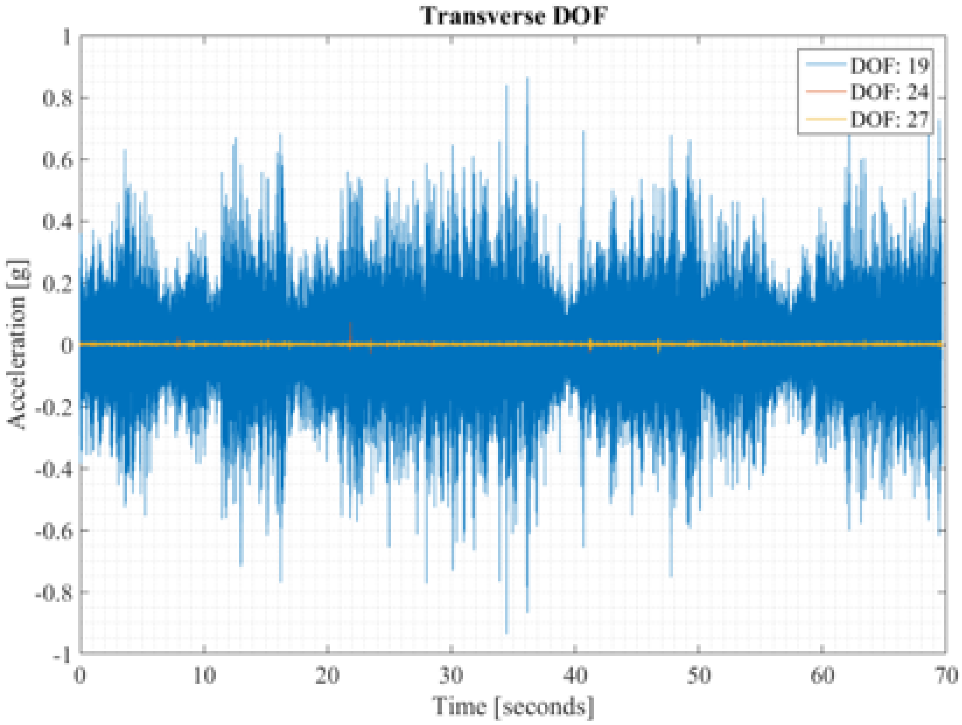
```
plot(tMins,data(:,ind));
title('Vertical DOF - Pier Cap');
xlabel('Time [minutes]')
ylabel('Acceleration [g]')
ylim([-1 1])
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```





Time Plots - Transverse DOF

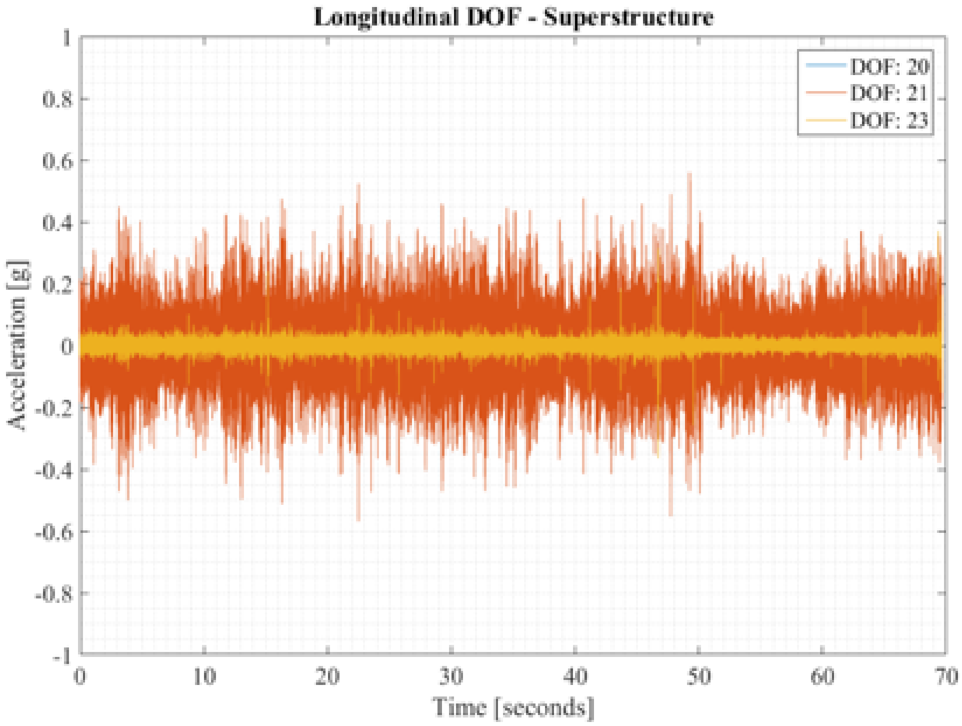
```
% plot vertical superstructure
ind = dof.trans.sub;
plot(tMins,data(:,ind));
title('Transverse DOF');
xlabel('Time [seconds]')
ylabel('Acceleration [g]')
ylim([-1 1])
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```

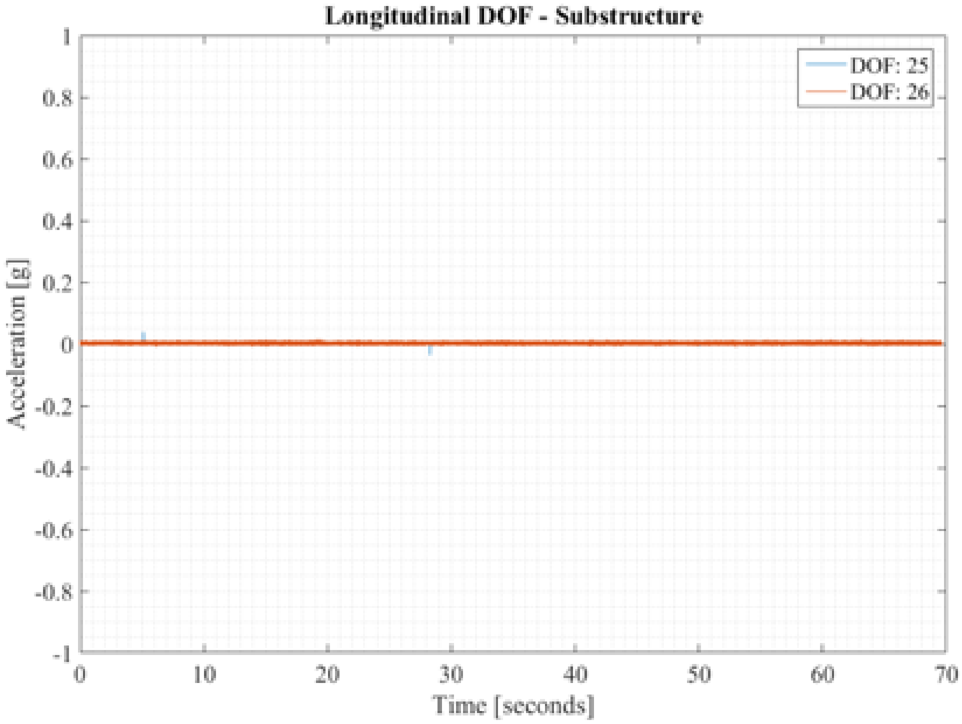


Time Plots - Longitudinal DOF

```
% plot vertical superstructure
ind = dof.long.super;
plot(tMins,data(:,ind));
title('Longitudinal DOF - Superstructure');
xlabel('Time [seconds]')
ylabel('Acceleration [g]')
ylim([-1 1])
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow

% plot vertical superstructure
ind = dof.long.sub;
plot(tMins,data(:,ind));
title('Longitudinal DOF - Substructure');
xlabel('Time [seconds]')
ylabel('Acceleration [g]')
ylim([-1 1])
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
```

```
snapnow
```


Longitudinal DOF - Superstructure
DOF: 20
DOF: 21
DOF: 23
Acceleration [g]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60
70
Time [seconds]


Longitudinal DOF - Substructure
DOF: 25
DOF: 26
Acceleration [g]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60
70
Time [seconds]

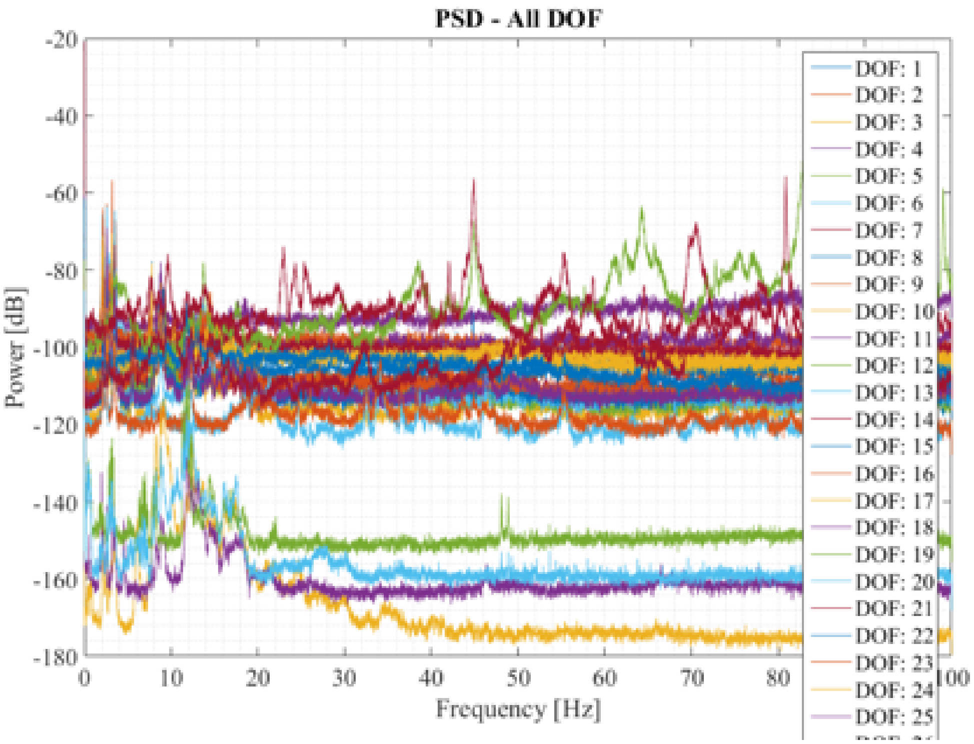
Power Spectral Density (PSD) - Plot All

Notes:

- Data record broken into 50 segments for averaging
- 75 percent overlap of each segment
- Default nfft

```
nAvg = 50;  % number of averages
perc = 75;  % percent overlap
nfft = [];  % use default nfft lines

% get psd
[pxx,f] = getpsd(data,nAvg,perc,nfft,fs);

% display frequency resolution
fprintf('Observable frequency range: 0-%s[Hz]\n',num2str(f(end)));
fprintf('Frequency resolution: %s[Hz]\n',num2str(f(2)));


ind = 1:size(data,2);
plot(f,mag2db(pxx(:,ind)))
title('PSD - All DOF');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```

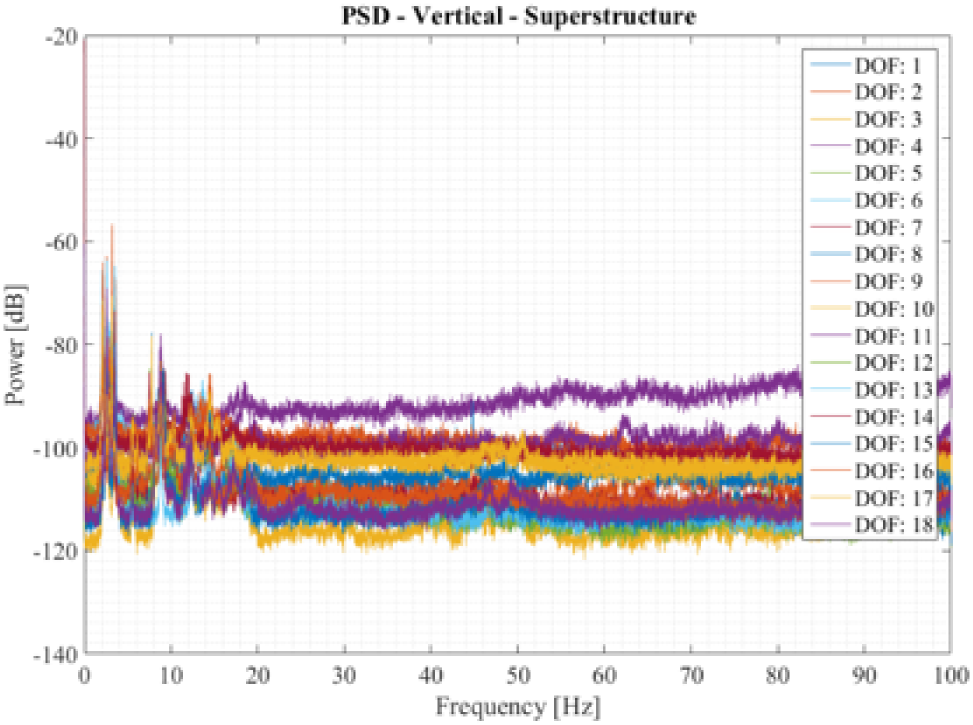
```
Power Spectral Density
 DOF: 1
 DOF: 2
 DOF: 3
 DOF: 4
 DOF: 5
 DOF: 6
 DOF: 7
 DOF: 8
 DOF: 9
 DOF: 10
 DOF: 11
 DOF: 12
 DOF: 13
 DOF: 14
 DOF: 15
 DOF: 16
 DOF: 17
 DOF: 18
 DOF: 19
 DOF: 20
 DOF: 21
 DOF: 22
 DOF: 23
 DOF: 24
 DOF: 25
 DOF: 26
 DOF: 27
 DOF: 28
Observable frequency range: 0-100[Hz]
Frequency resolution: 0.0061035[Hz]
```

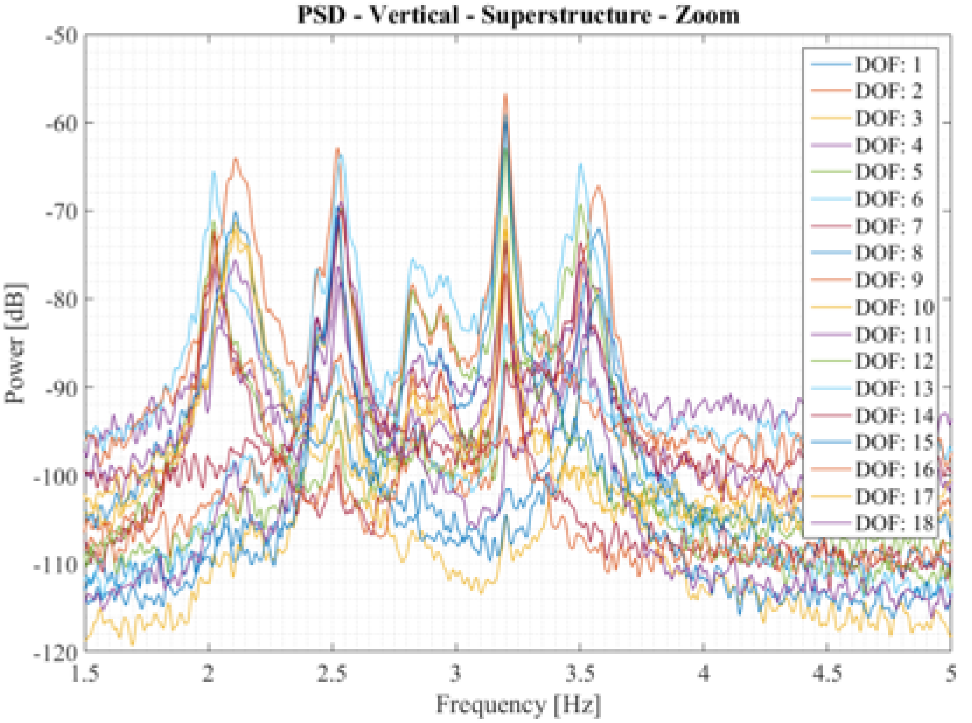


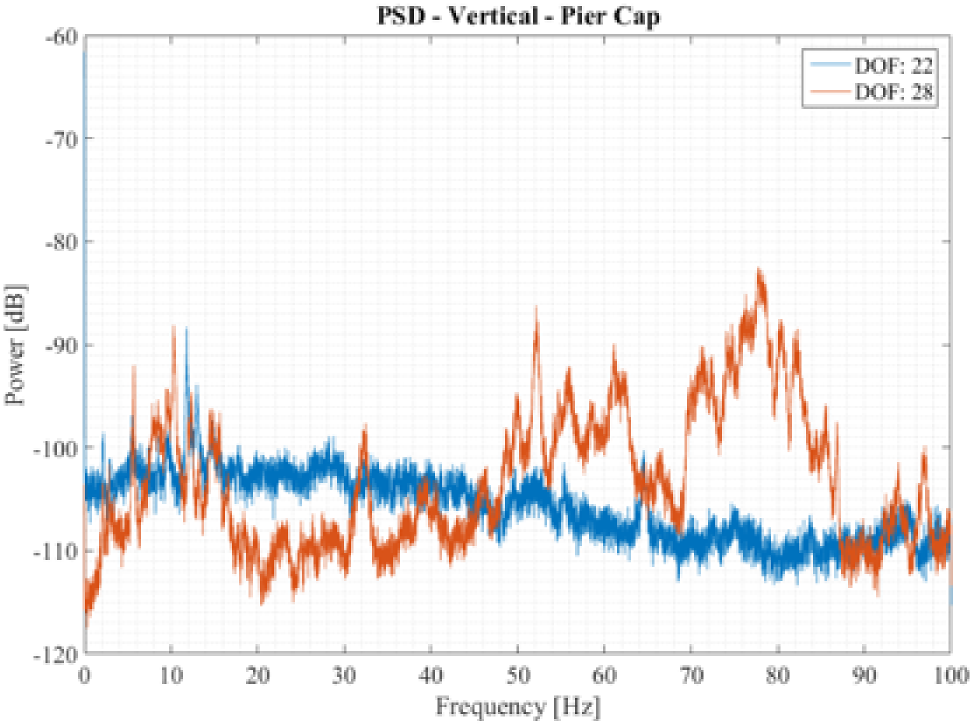
PSD - Plot Vertical

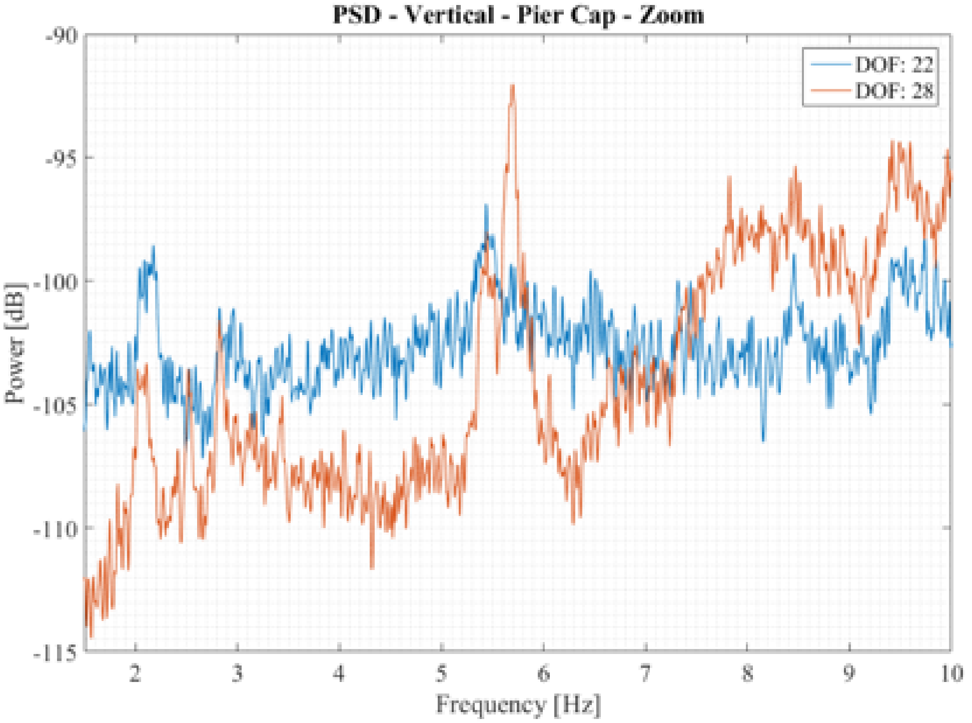
```
% full freq plot
ind = dof.vert.super;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Vertical - Superstructure');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```

```
% zoom to narrow freq bandwidth
bnds = [1.5 5]; % freq bnds
ind = dof.vert.super;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Vertical - Superstructure - Zoom');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
xlim(bnds)
grid minor
legend(dof.labels(ind))
lh = get(gca,'children');   % find line handles of current axes
set(lh,'linewidth',1);      % set linewidth
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow


% PIER CAP - full freq plot
ind = dof.vert.sub;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Vertical - Pier Cap');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow


% PIER CAP - zoom to narrow freq bandwidth
bnds = [1.5 10]; % freq bnds
ind = dof.vert.sub;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Vertical - Pier Cap - Zoom');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
xlim(bnds)
grid minor
legend(dof.labels(ind))
lh = get(gca,'children');   % find line handles of current axes
set(lh,'linewidth',1);      % set linewidth
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```


PSD - Vertical - Superstructure
Power [dB]
-20
-40
-60
-80
-100
-120
-140
Frequency [Hz]
0
10
20
30
40
50
60
70
80
90
100
DOF: 1
DOF: 2
DOF: 3
DOF: 4
DOF: 5
DOF: 6
DOF: 7
DOF: 8
DOF: 9
DOF: 10
DOF: 11
DOF: 12
DOF: 13
DOF: 14
DOF: 15
DOF: 16
DOF: 17
DOF: 18


PSD - Vertical - Superstructure - Zoom
Power [dB]
-50
-60
-70
-80
-90
-100
-110
-120
Frequency [Hz]
1.5
2
2.5
3
3.5
4
4.5
5
DOF: 1
DOF: 2
DOF: 3
DOF: 4
DOF: 5
DOF: 6
DOF: 7
DOF: 8
DOF: 9
DOF: 10
DOF: 11
DOF: 12
DOF: 13
DOF: 14
DOF: 15
DOF: 16
DOF: 17
DOF: 18

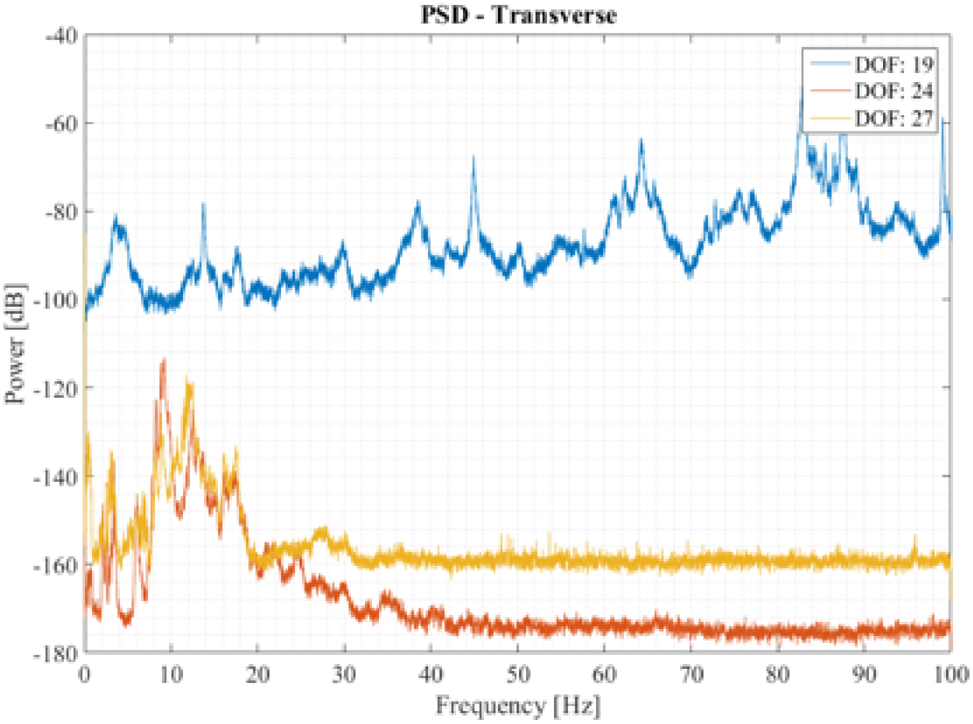




PSD - Plot Transverse

```
% full freq plot
ind = dof.trans.sub;
```

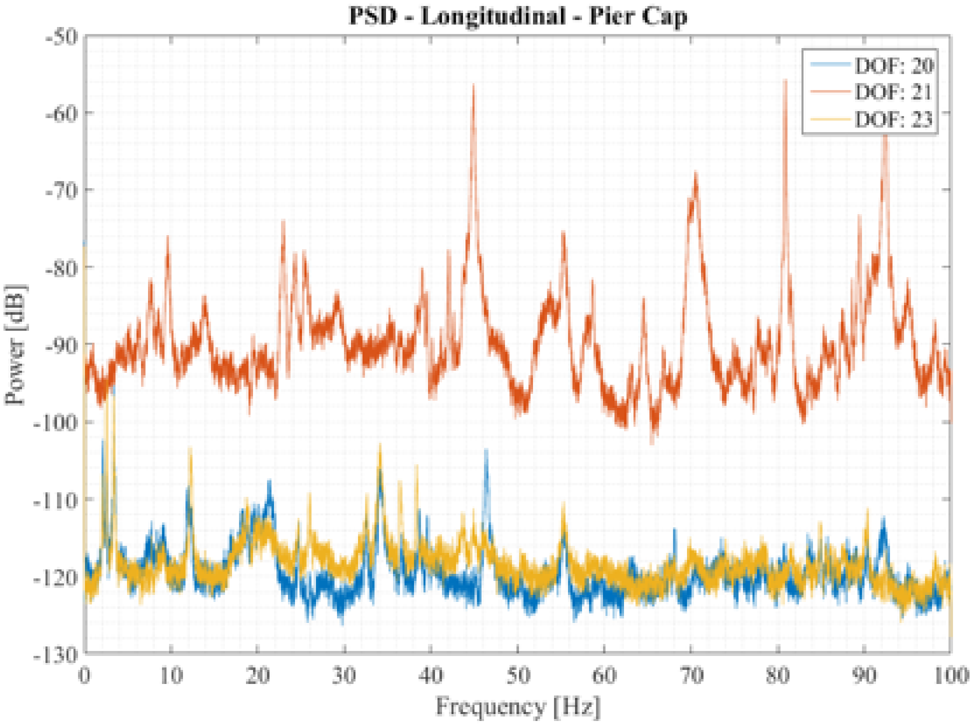
```
plot(f,mag2db(pxx(:,ind)))
title('PSD - Transverse');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```

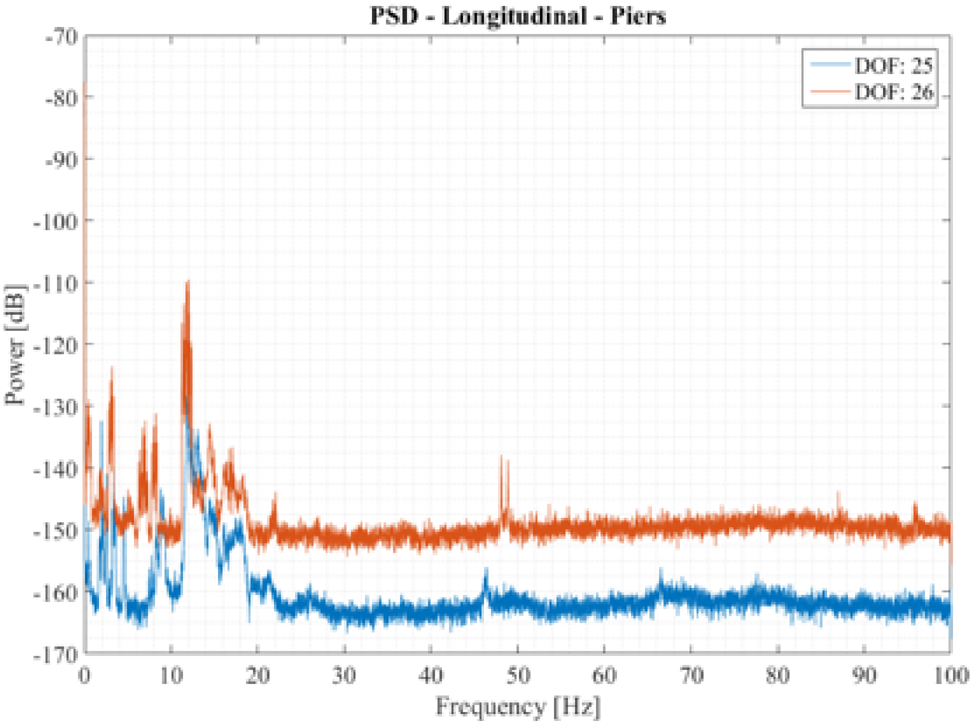


PSD - Plot Longitudinal

```
% full freq plot
ind = dof.long.super;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Longitudinal - Pier Cap');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow


% full freq plot
```

```
ind = dof.long.sub;
plot(f,mag2db(pxx(:,ind)))
title('PSD - Longitudinal - Piers');
xlabel('Frequency [Hz]')
ylabel('Power [dB]')
grid minor
legend(dof.labels(ind))
ah = gca;
ah.FontName = 'Times';
ah.FontSize = 18;
snapnow
```





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