

# Data analysis of Engine run on Friday May 3rd 2019

- Duration of run was
- Captured vibration data (3D) and OBD data

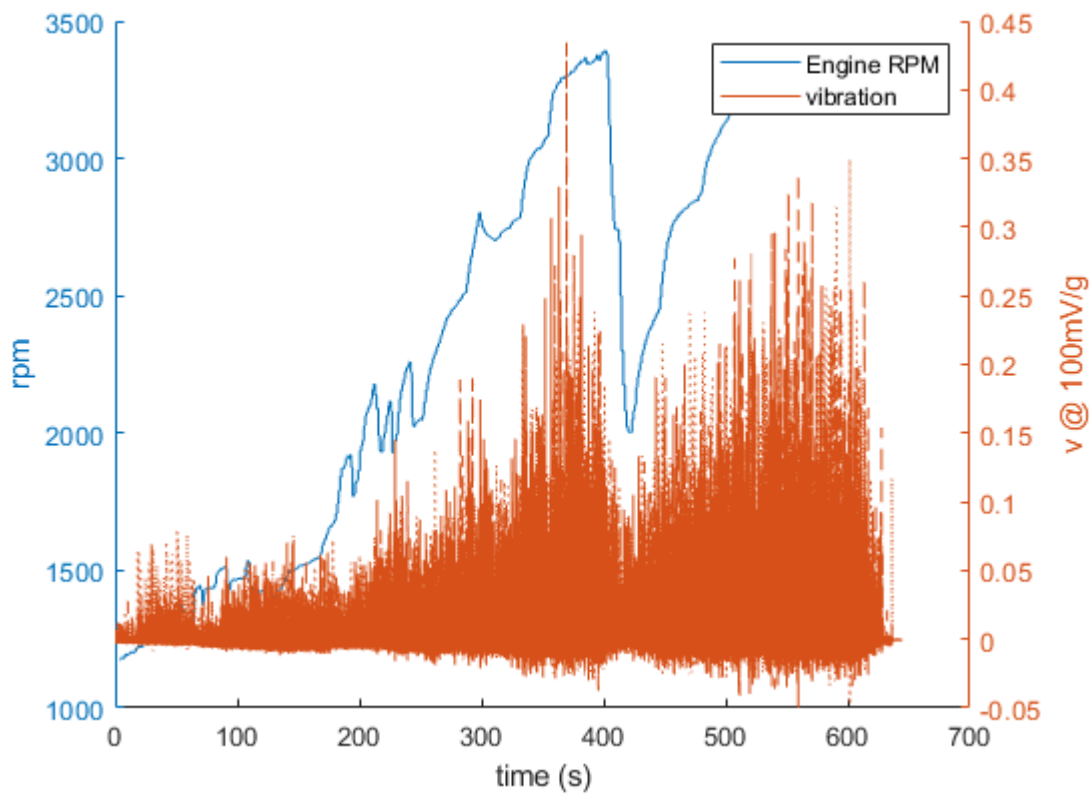
## read obd and accelerometer data files

```
obd = readmatrix('obd_friday_main.csv');  
acc = readmatrix('test_friday_real.csv');
```

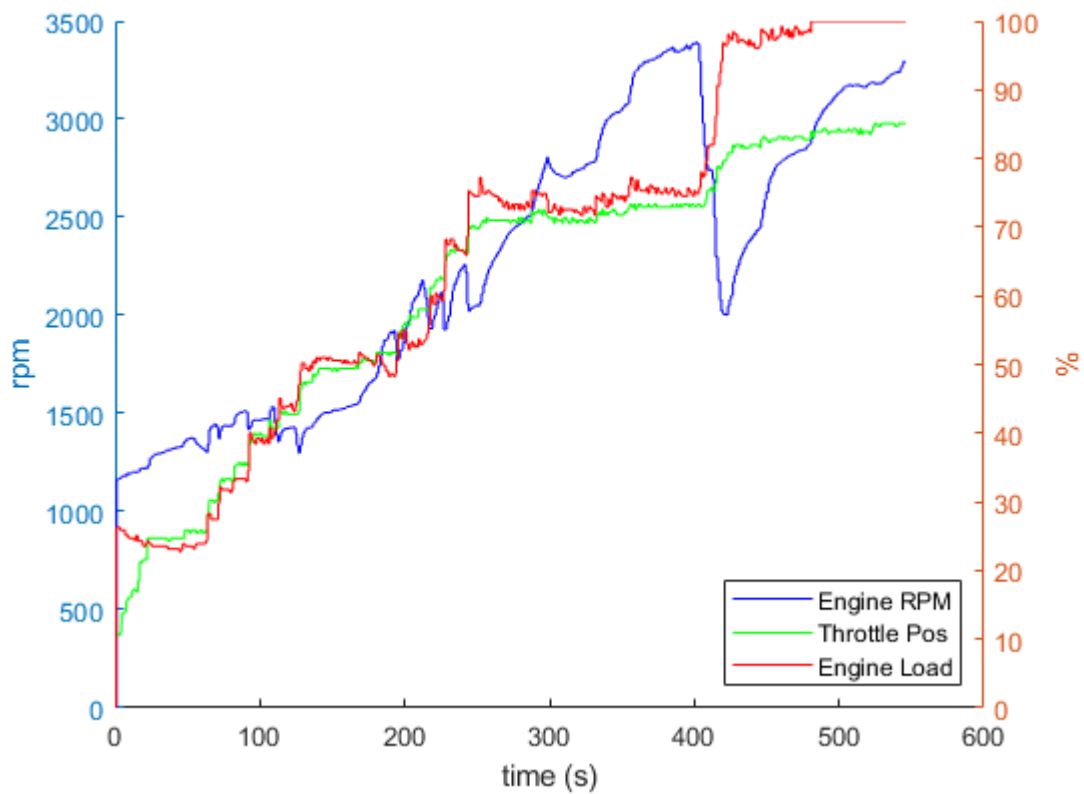
```
obd_t = obd(:,1);  
obd_2 = obd(:,2);  
obd_tpos = obd(:,3);  
obd_load = obd(:,4);  
obd_5 = obd(:,5);  
obd_ctemp = obd(:,6);  
obd_rpm = obd(:,7);  
obd_ignt = obd(:,8);  
obd_vin = obd(:,9);  
obd_airt = obd(:,10);  
obd_map = obd(:,11);  
obd_12 = obd(:,12);  
obd_13 = obd(:,13);  
obd_14 = obd(:,14);  
obd_15 = obd(:,15);  
obd_16 = obd(:,16);
```

```
acc_t = acc(:,1);  
acc_x = acc(:,2);  
acc_y = acc(:,4);  
acc_z = acc(:,6);  
  
acc_x(isnan(acc_x))=0;  
acc_y(isnan(acc_y))=0;  
acc_z(isnan(acc_z))=0;
```

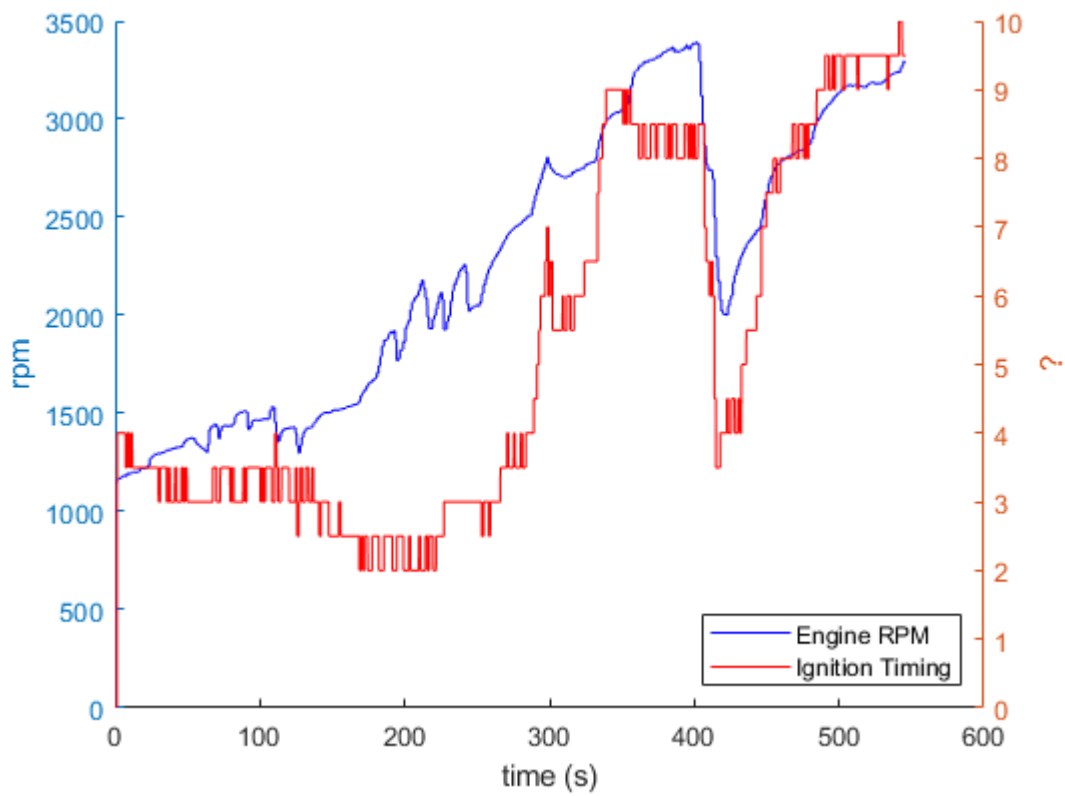
```
f1 = figure(1); clf;  
hold on;  
yyaxis left;  
plot(obd_t(71:end), obd_rpm(71:end)); % time alignment  
ylabel("rpm");  
yyaxis right;  
plot(acc_t, acc_x);  
plot(acc_t, acc_y);  
plot(acc_t, acc_z);  
ylabel("v @ 100mV/g");  
hold off;  
legend({"Engine RPM", "vibration"});  
xlabel("time (s)");
```



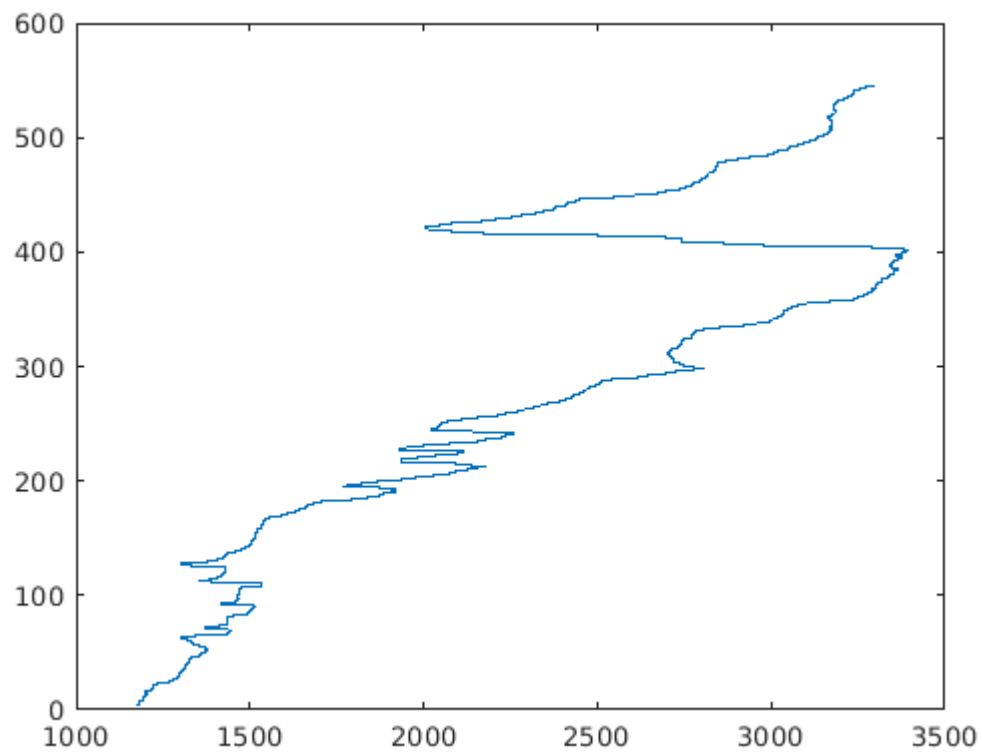
```
f22 = figure(22); clf;
hold on;
yyaxis left;
plot(obd_t, obd_rpm, 'b');
ylabel("rpm");
yyaxis right;
plot(obd_t, obd_tpos, 'g-');
plot(obd_t, obd_load, 'r-');
ylabel("%");
hold off;
legend({"Engine RPM", "Throttle Pos", "Engine Load"}, 'location', 'southeast');
xlabel("time (s)");
```



```
f23 = figure(23); clf;
hold on;
yyaxis left;
plot(obd_t, obd_rpm, 'b');
ylabel("rpm");
yyaxis right;
plot(obd_t, obd_ignt, 'r');
ylabel("%");
hold off;
legend({"Engine RPM", "Ignition Timing"}, 'location', 'southeast');
xlabel("time (s)");
```



```
rpm_temp = obd_rpm(71:end);
obd_t_temp = obd_t(71:end);
acc_t_temp = acc_t(1:3494500);
acc_x_temp = acc_x(1:3494500);
```

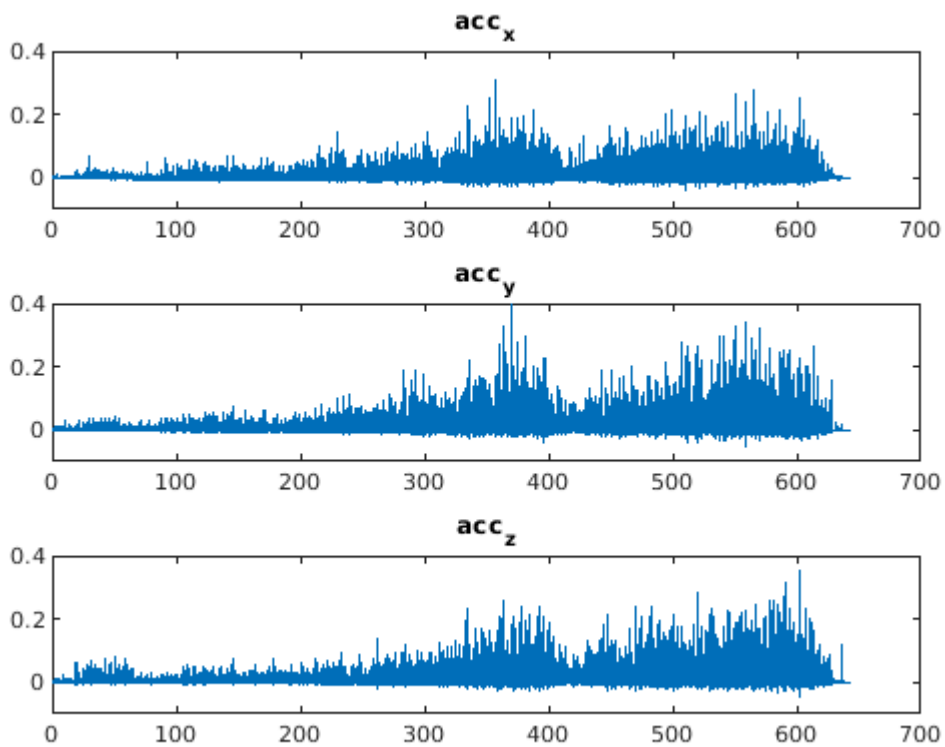


```
f3 = figure(3); clf;
%f3.Position = [0 0 1200 800];
title('raw accelerometer data');

subplot(311);
plot(acc_t, acc_x);
title('acc_x');
ylim([-0.1 0.4]);

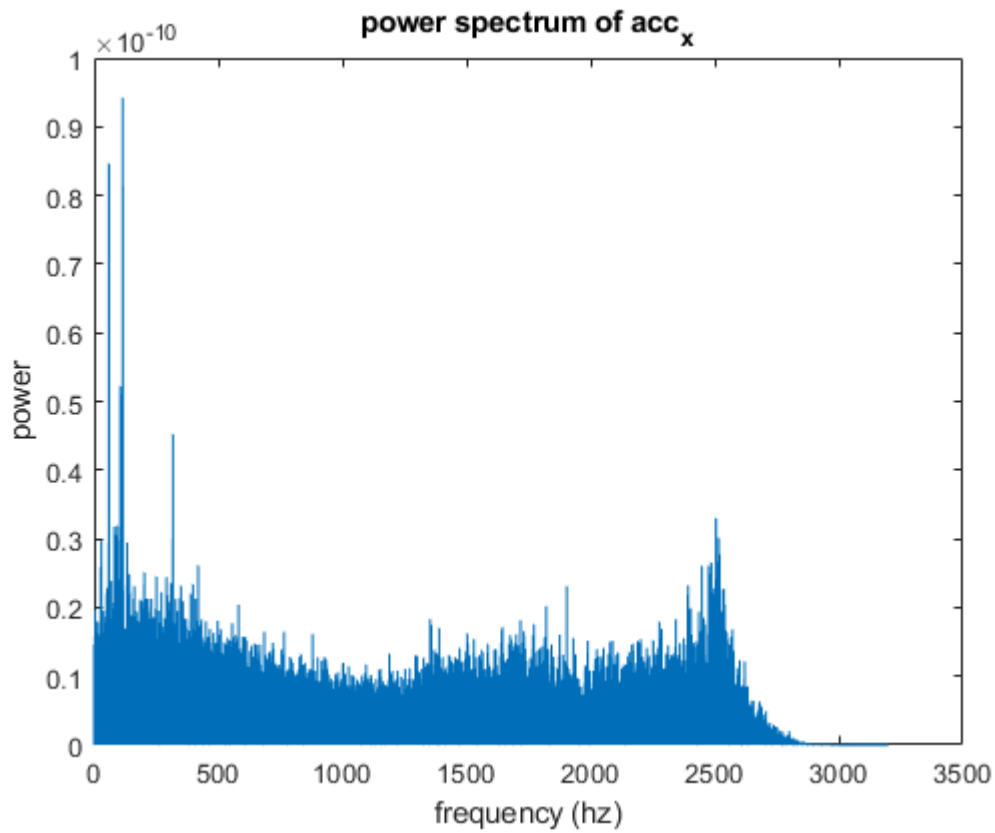
subplot(312);
plot(acc_t, acc_y);
title('acc_y');
ylim([-0.1 0.4]);

subplot(313);
plot(acc_t, acc_z);
title('acc_z');
ylim([-0.1 0.4]);
```

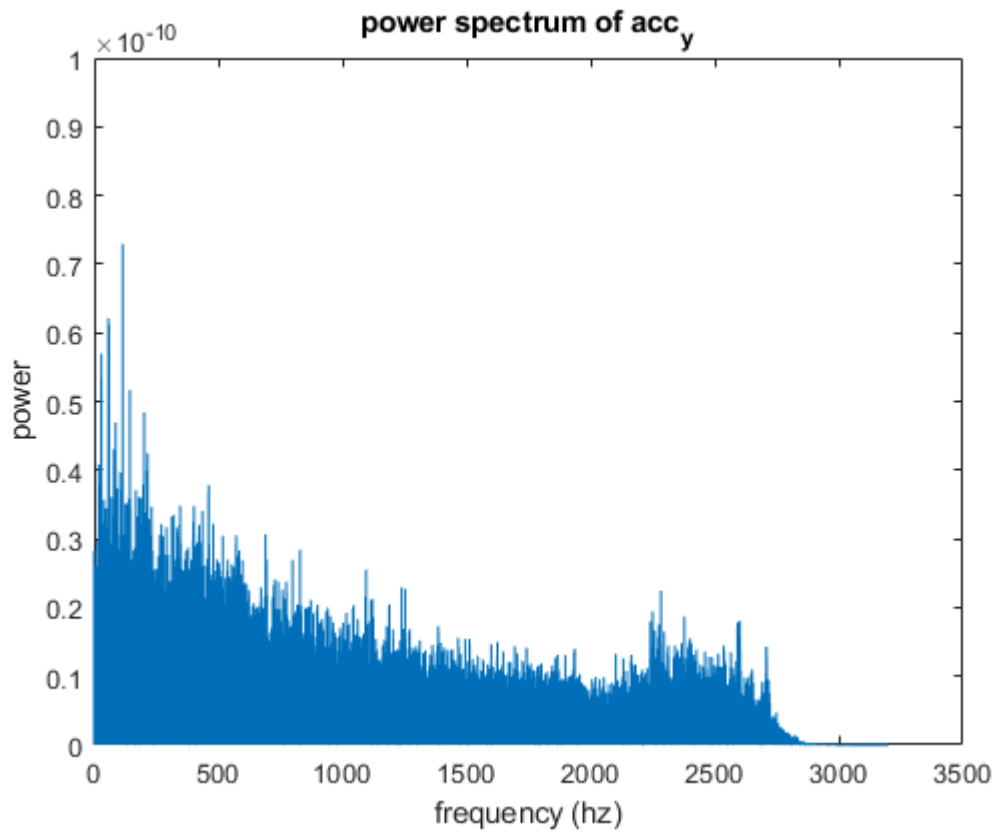


## Spectral Analysis

```
sample_rate = 6400;
N = length(acc_t);
t = (0:N-1)/sample_rate;
hz_vals = linspace(0, sample_rate/2, floor(N/2)+1);
powers_x = abs(fft(detrend(acc_x(:,1)))/N).^2;
f24 = figure(24); clf;
plot(hz_vals, powers_x(1:length(hz_vals)));
xlabel("frequency (hz)");
ylabel("power");
title("power spectrum of acc_x");
```

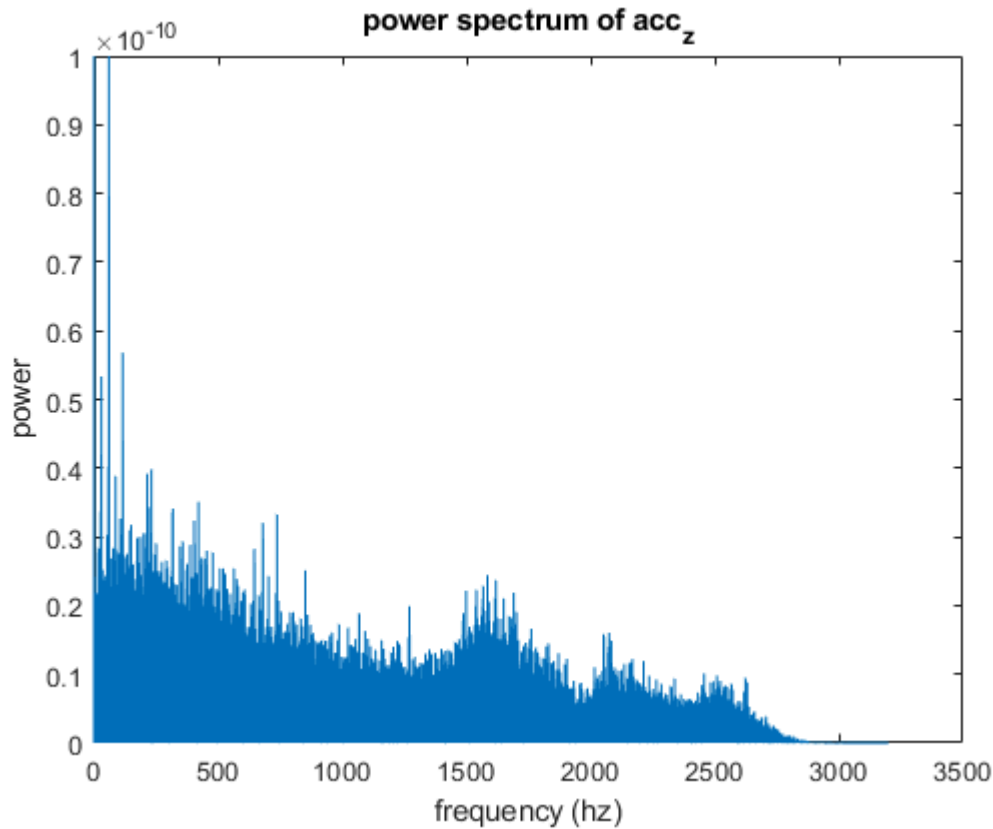


```
powers_y = abs(fft(detrend(acc_y(:,1)))/N).^2;
f25 = figure(25); clf;
plot(hz_vals, powers_y(1:length(hz_vals)));
ylim([0 10^-10])
xlabel("frequency (hz)");
ylabel("power");
title("power spectrum of acc_y");
```



```
powers_z = abs(fft(detrend(acc_z(:,1)))/N).^2;
f25 = figure(25); clf;
plot(hz_vals, powers_z(1:length(hz_vals)));
ylim([0 10^-10]);
xlabel("frequency (hz)");
ylabel("power");
title("power spectrum of acc_z");
```

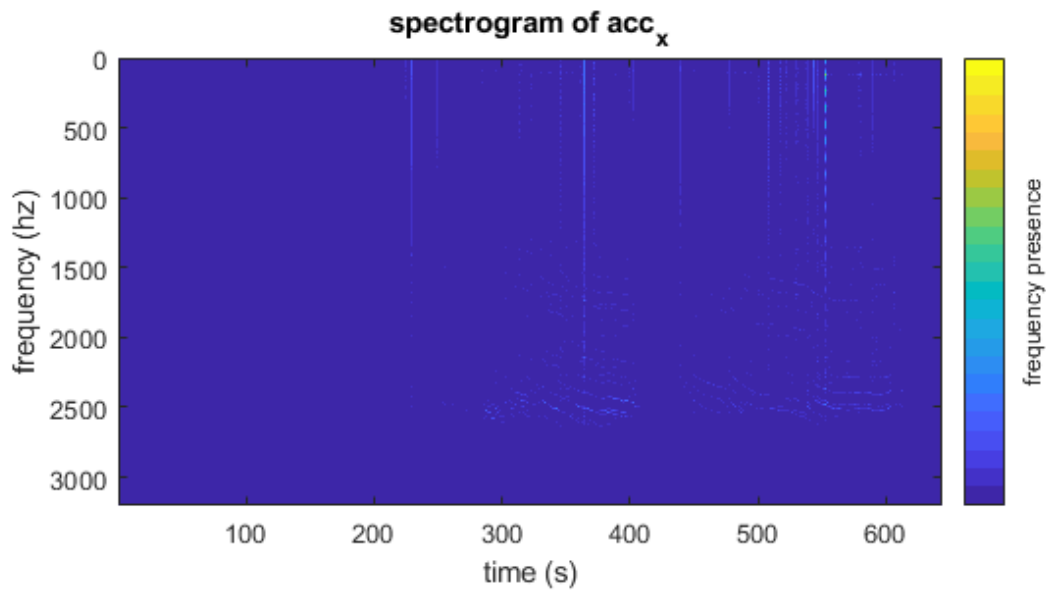




```
%powers = abs(fft(acc_x(:,1))/N).^2;
```

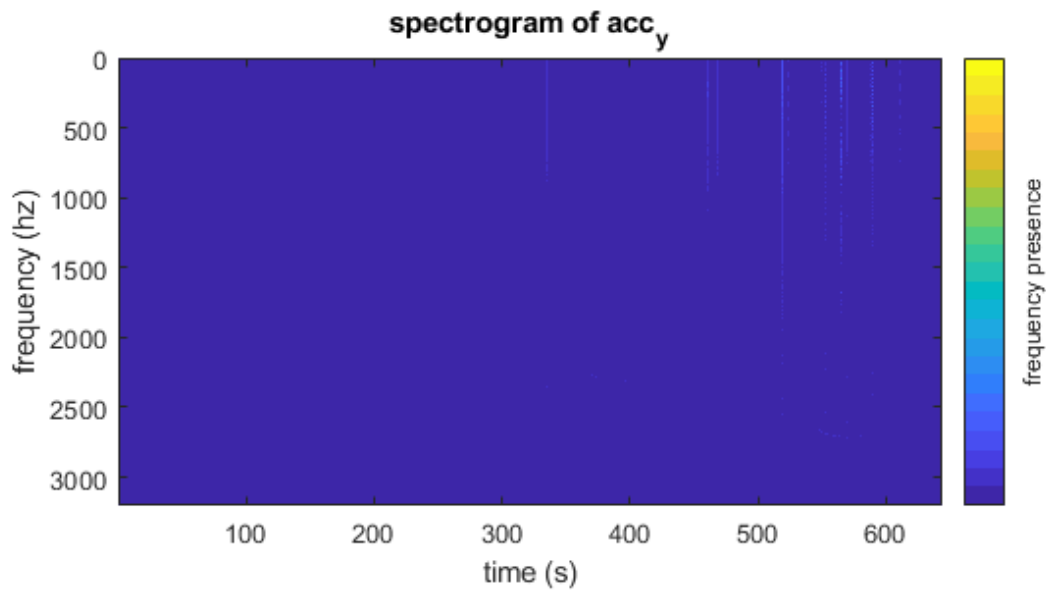
```
[spectrumx, frequencyx, timex] = spectrogram(detrend(acc_x(:,1)), hann(1000), 100, [], sample_r
```

```
f26 = figure(26); clf;
f26.Position = [0 0 600 300];
imagesc(timex, frequencyx, abs(spectrumx).^2);
ax = gca;
%ax.CLim = [8 12];
%ax.YLim = frequency([1 dsearchn(frequency, 12000)]);
%ax.XLim = time([1 end]);
colormap(parula(24));
c = colorbar();
c.Label.String = "frequency presence";
set(c, 'YTick', []);
xlabel("time (s)");
ylabel("frequency (hz)");
title("spectrogram of acc_x");
```



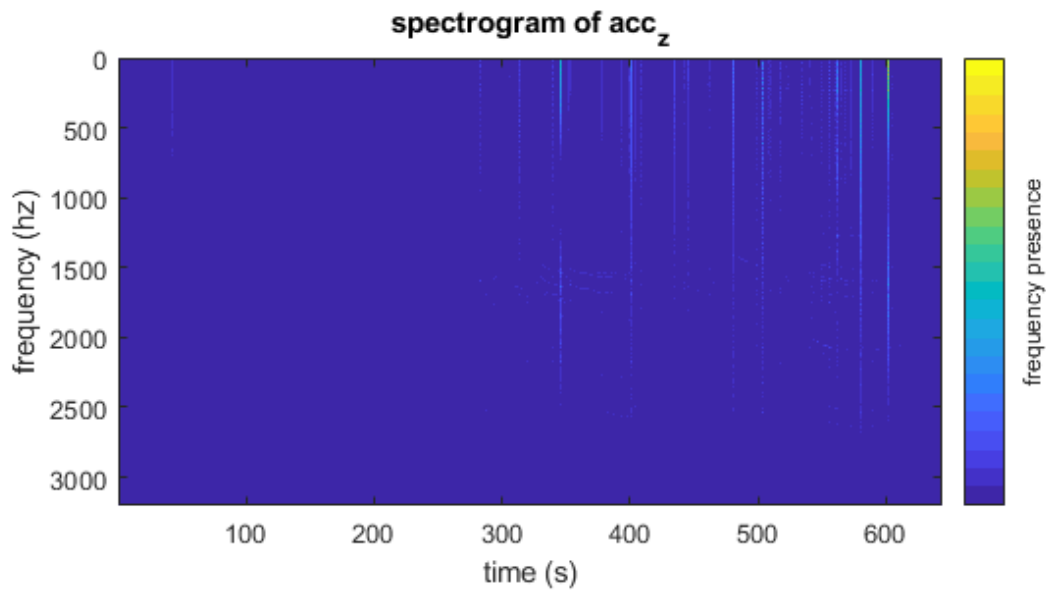
```
[spectrumy, frequencyy, timey] = spectrogram(detrend(acc_y(:,1)), hann(1000), 100, [], sample_r

f26 = figure(26); clf;
f26.Position = [0 0 600 300];
imagesc(timey, frequencyy, abs(spectrumy).^2);
ax = gca;
%ax.CLim = [8 12];
%ax.YLim = frequency([1 dsearchn(frequency, 12000)]);
%ax.XLim = time([1 end]);
colormap(parula(24));
c = colorbar();
c.Label.String = "frequency presence";
set(c, 'YTick', []);
xlabel("time (s)");
ylabel("frequency (hz)");
title("spectrogram of acc_y");
```



```
[spectrumz, frequencyz, timez] = spectrogram(detrend(acc_z(:,1)), hann(1000), 100, [], sample_r

f26 = figure(26); clf;
f26.Position = [0 0 600 300];
imagesc(timez, frequencyz, abs(spectrumz).^2);
ax = gca;
%ax.CLim = [8 12];
%ax.YLim = frequency([1 dsearchn(frequency, 12000)]);
%ax.XLim = time([1 end]);
colormap(parula(24));
c = colorbar();
c.Label.String = "frequency presence";
set(c, 'YTick', []);
xlabel("time (s)");
ylabel("frequency (hz)");
title("spectrogram of acc_z");
```



```
f4 = figure(4); clf;
f4.Position = [0 0 1200 800];
subplot(311);
plot(hz_vals, fft(acc_x(1:length(hz_vals))));
```

Warning: Imaginary parts of complex X and/or Y arguments ignored

```
title("FFT of acc_x");
ylim([-10 10]);

subplot(312);
%plot(hz_vals, powers(1:length(hz_vals)));
plot(hz_vals, fft(acc_y(1:length(hz_vals))));
```

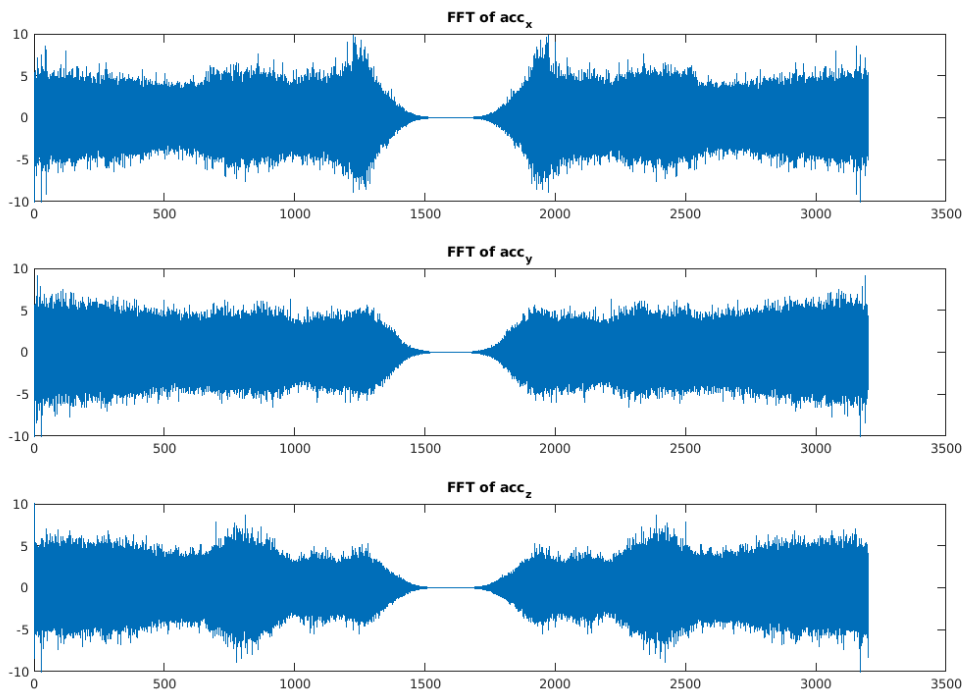
Warning: Imaginary parts of complex X and/or Y arguments ignored

```
title("FFT of acc_y");
ylim([-10 10]);

subplot(313);
%plot(hz_vals, powers(1:length(hz_vals)));
plot(hz_vals, fft(acc_z(1:length(hz_vals))));
```

Warning: Imaginary parts of complex X and/or Y arguments ignored

```
title("FFT of acc_z");
ylim([-10 10]);
```



```

fs = 1024;
npnts = fs*5+1;
timevec = (1:npnts)/fs;
timevec = timevec - mean(timevec);
hz = linspace(0, fs/2, floor(npnts/2)+1);
freq = 4;
csw = cos(2*pi*freq*timevec);
fwhm = .5;
gaussian = exp(-(4*log(2)*timevec.^2) / fwhm^2);

morletWavelet = csw .* gaussian;
morletP = abs(fft(morletWavelet)/npnts);

haarWavelet = zeros(npnts,1);
haarWavelet(dsearchn(timevec',0):dsearchn(timevec',.5)) = 1;
haarWavelet(dsearchn(timevec',.5):dsearchn(timevec',1-1/fs)) = -1;
haarP = abs(fft(haarWavelet)/npnts);

s = .4;
sombbreroWavelet = (2/(sqrt(3*s)*pi^.25)) .* (1-(timevec.^2)/(s^2)) .* exp((-timevec.^2)./(2*s^2));
sombbreroP = abs(fft(sombbreroWavelet)/npnts);

spos = .1;
sneg = .5;

gauss1 = exp((-timevec.^2) / (2*spos^2)) / (spos*sqrt(2*pi));
gauss2 = exp((-timevec.^2) / (2*sneg^2)) / (sneg*sqrt(2*pi));
dogWavelet = gauss1 - gauss2;

```

```

dogP = abs(fft(dogWavelet)/npnts);

f30 = figure(30); clf;
f30.Position = [0 0 1600 1200];
subplot(4,2,1);
plot(timevec, morletWavelet);
title("Time Domain");
ylabel("Morlet Wavelet");

subplot(4,2,2);
plot(hz, morletP(1:length(hz)));
xlim([0 freq*3]);
title("Frequency Domain");

subplot(4,2,3);
plot(timevec, haarWavelet);
ylabel("Haar Wavelet");

subplot(4,2,4);
plot(hz, haarP(1:length(hz)));
xlim([0 freq*3]);

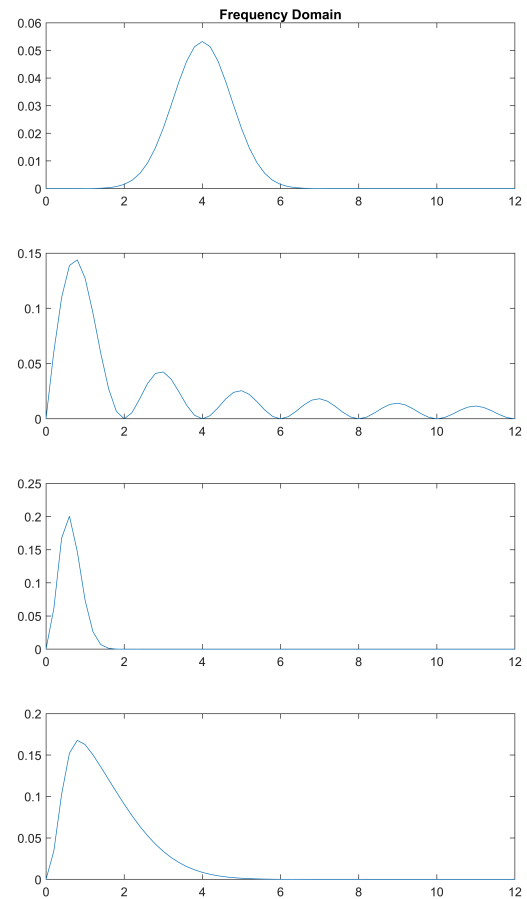
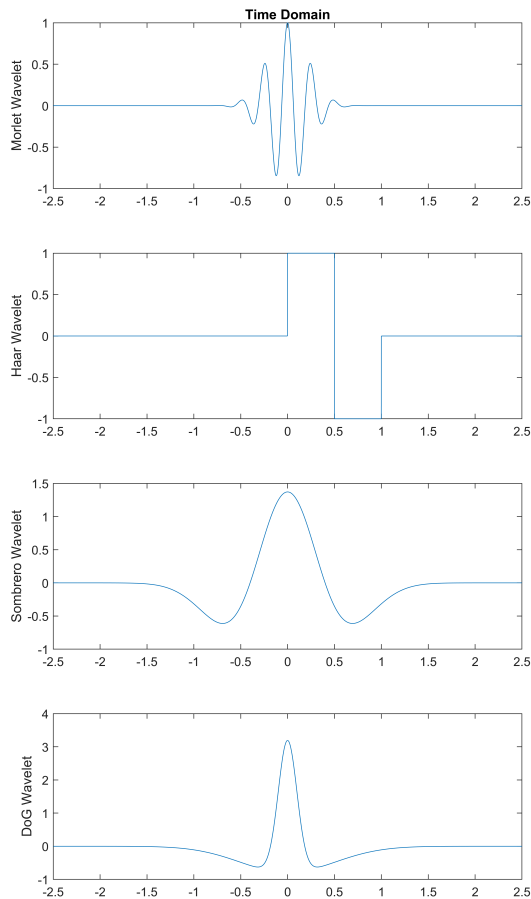
subplot(4,2,5);
plot(timevec, sombreroWavelet);
ylabel("Sombrero Wavelet");

subplot(4,2,6);
plot(hz, sombreroP(1:length(hz)));
xlim([0 freq*3]);

subplot(4,2,7);
plot(timevec, dogWavelet);
ylabel("DoG Wavelet");

subplot(4,2,8);
plot(hz, dogP(1:length(hz)));
xlim([0 freq*3]);

```



```

signal1 = acc_x(1:floor(length(acc_x)*.15));

srate = 6400;
N = length(signal1);
tv = (1:N)/srate;
tv = tv - mean(tv);
hzv = linspace(0, srate/2, floor(N/2)+1);

morewav1 = conv(signal1, morletWavelet, 'same');
haarwav1 = conv(signal1, haarWavelet, 'same');
mexiwav1 = conv(signal1, sombreroWavelet, 'same');

morewav1P = abs(fft(morewav1)/npnts);
haarwav1P = abs(fft(haarwav1)/npnts);
mexiwav1P = abs(fft(mexiwav1)/npnts);

f31 = figure(31); clf;
f31.Position = [0 0 1200 1200];
subplot(3,2,[1:2]);
plot(tv, signal1);
ylabel("V");

```

```

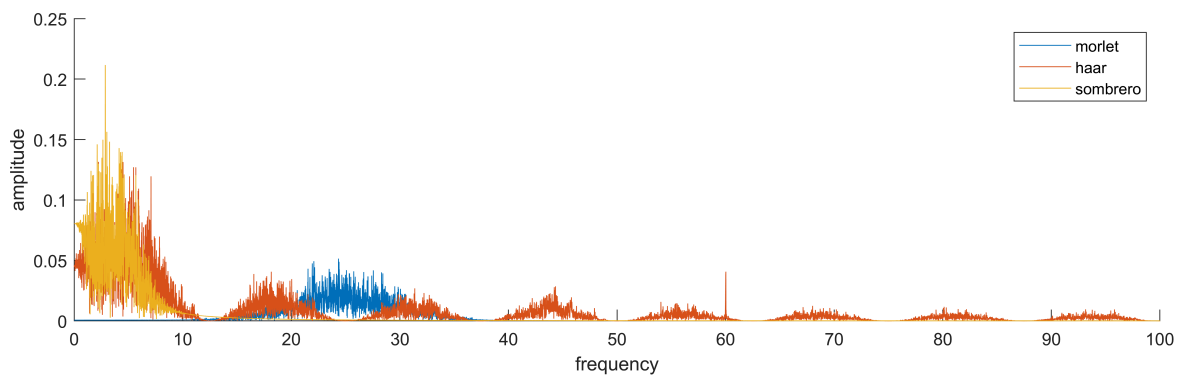
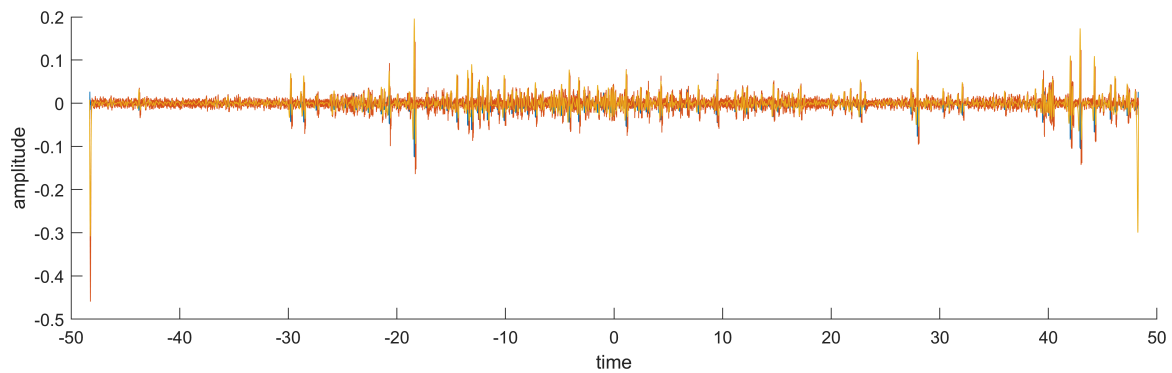
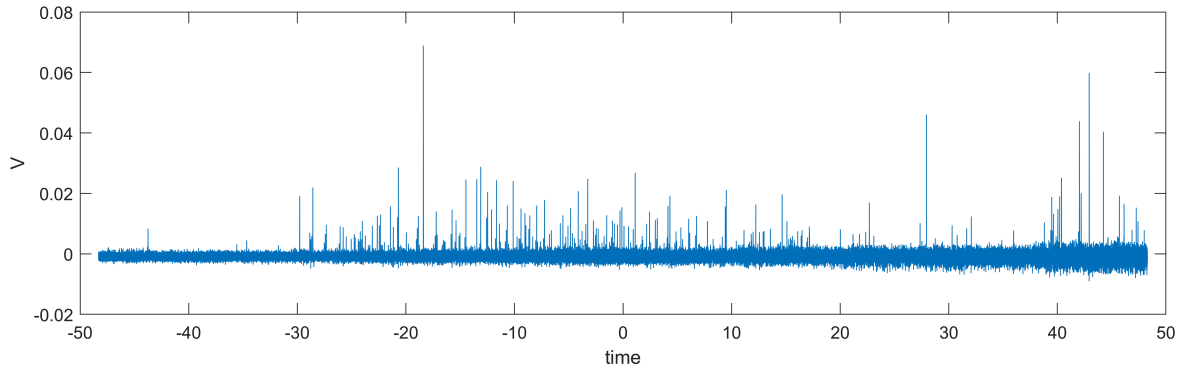
xlabel("time");

subplot(3,2,[3:4]);
hold on;
plot(tv, morewav1);
plot(tv, haarwav1);
plot(tv, mexiwav1);
hold off;
ylabel("amplitude");
xlabel("time");

subplot(3,2,[5:6]);
hold on;
plot(hzv, morewav1P(1:length(hzv)));
plot(hzv, haarwav1P(1:length(hzv)));
plot(hzv, mexiwav1P(1:length(hzv)));
xlim([0 100]);
ylabel("amplitude");
xlabel("frequency");
legend({"morlet", "haar", "sombbrero"});
hold off;

```





```
signal2 = acc_x(floor(length(acc_x)*.75):floor(length(acc_x)*.9));
```

```
srate = 6400;
```

```
N = length(signal2);
```

```
tv = (1:N)/srate;
```

```
tv = tv - mean(tv);
```

```
hzv = linspace(0, srate/2, floor(N/2)+1);
```

```
morewav1 = conv(signal2, morletWavelet, 'same');
```

```
haarwav1 = conv(signal2, haarWavelet, 'same');
```

```

mexiwav1 = conv(signal2, sombreroWavelet, 'same');

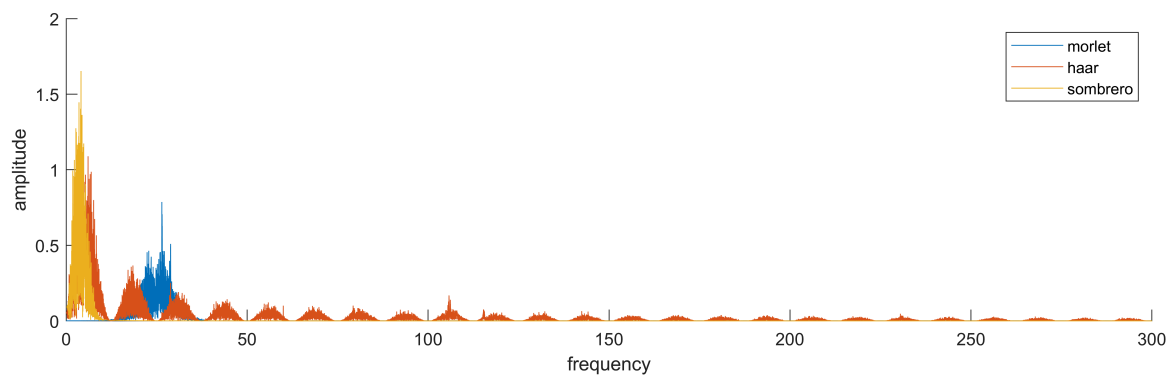
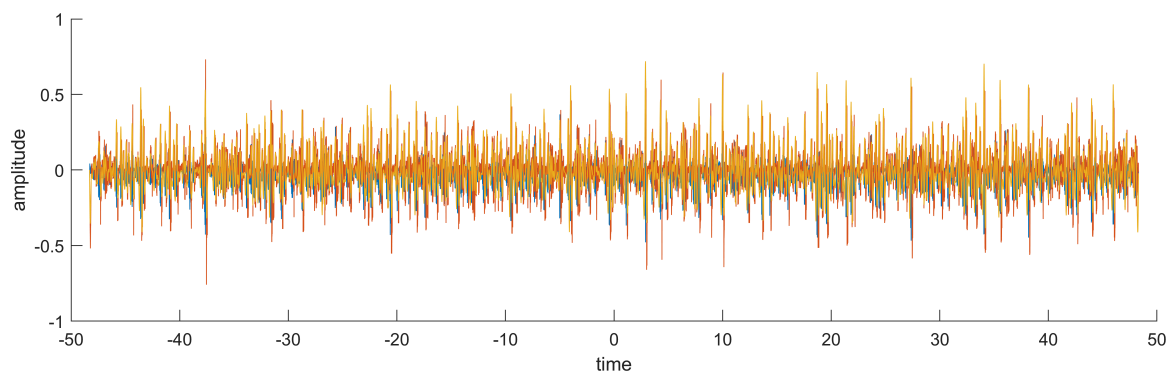
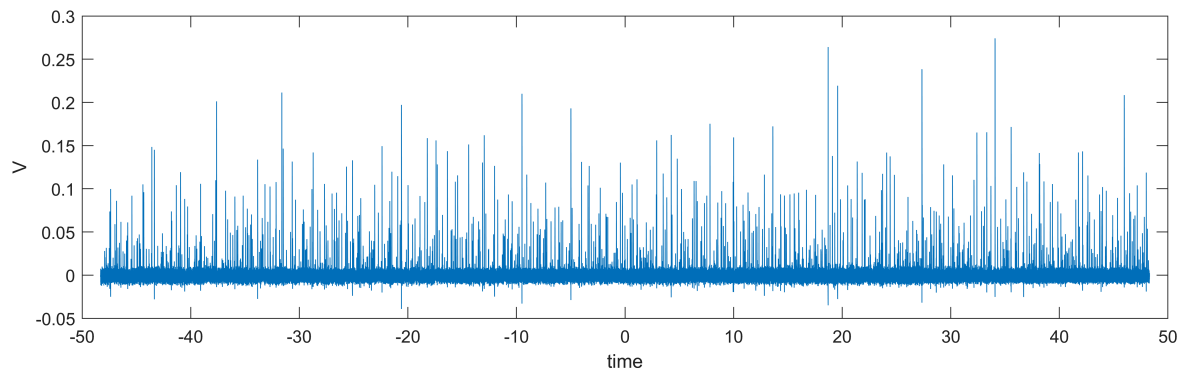
morewav1P = abs(fft(morewav1)/npnts);
haarwav1P = abs(fft(haarwav1)/npnts);
mexiwav1P = abs(fft(mexiwav1)/npnts);

f32 = figure(32); clf;
f32.Position = [0 0 1200 1200];
subplot(3,2,[1:2]);
plot(tv, signal2);
ylabel("V");
xlabel("time");

subplot(3,2,[3:4]);
hold on;
plot(tv, morewav1);
plot(tv, haarwav1);
plot(tv, mexiwav1);
hold off;
ylabel("amplitude");
xlabel("time");

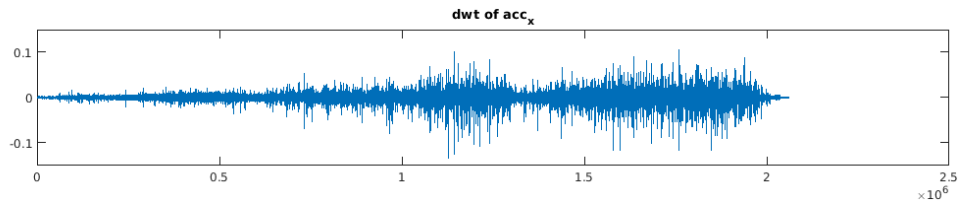
subplot(3,2,[5:6]);
hold on;
plot(hzv, morewav1P(1:length(hzv)));
plot(hzv, haarwav1P(1:length(hzv)));
plot(hzv, mexiwav1P(1:length(hzv)));
xlim([0 300]);
ylabel("amplitude");
xlabel("frequency");
legend({"morlet", "haar", "sombrero"});
hold off;

```

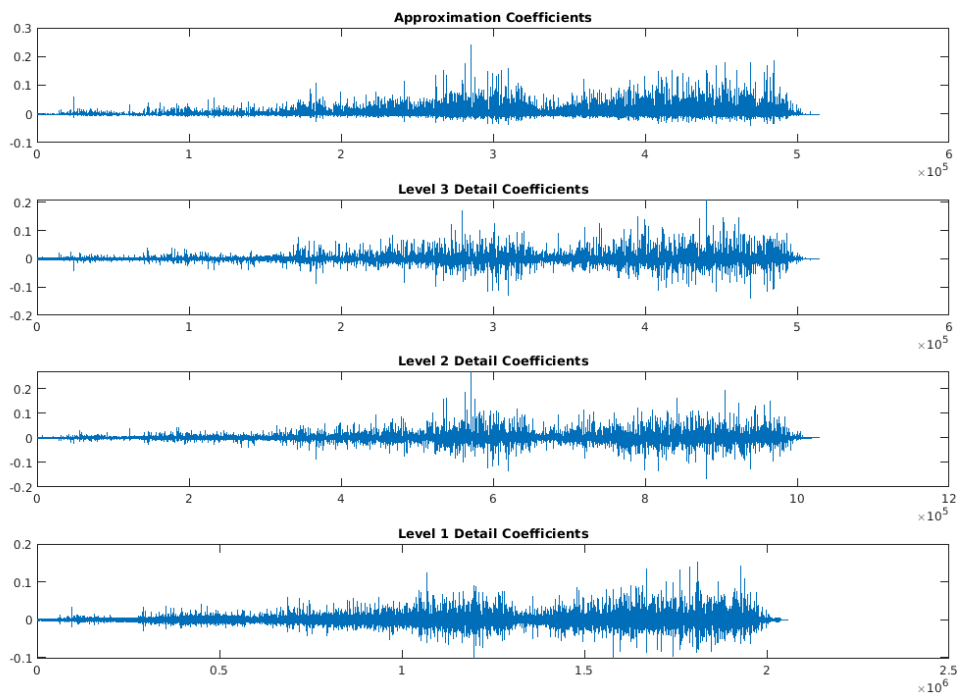


## DWT of acc\_x

```
[cA, cD] = dwt(acc_x, 'sym4');
f5 = figure(5); clf;
f5.Position = [0 0 1200 200];
plot(cD);
title("dwt of acc_x");
```



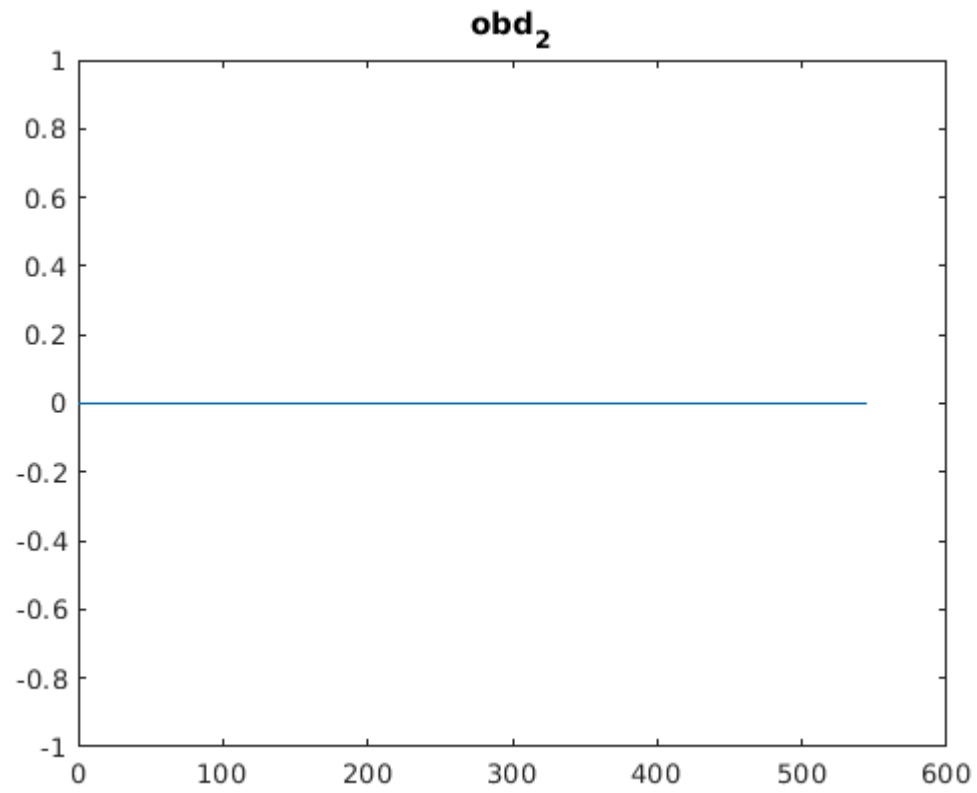
```
[c,l] = wavedec(acc_x, 3, 'db2');
approx = appcoef(c,l,'db2');
[cd1,cd2,cd3] = detcoef(c,l,[1 2 3]);
f6 = figure(6); clf;
f6.Position = [0 0 1200 800];
subplot(4,1,1);
plot(approx);
title('Approximation Coefficients');
subplot(4,1,2);
plot(cd3);
title('Level 3 Detail Coefficients');
subplot(4,1,3);
plot(cd2);
title('Level 2 Detail Coefficients');
subplot(4,1,4);
plot(cd1);
title('Level 1 Detail Coefficients');
```



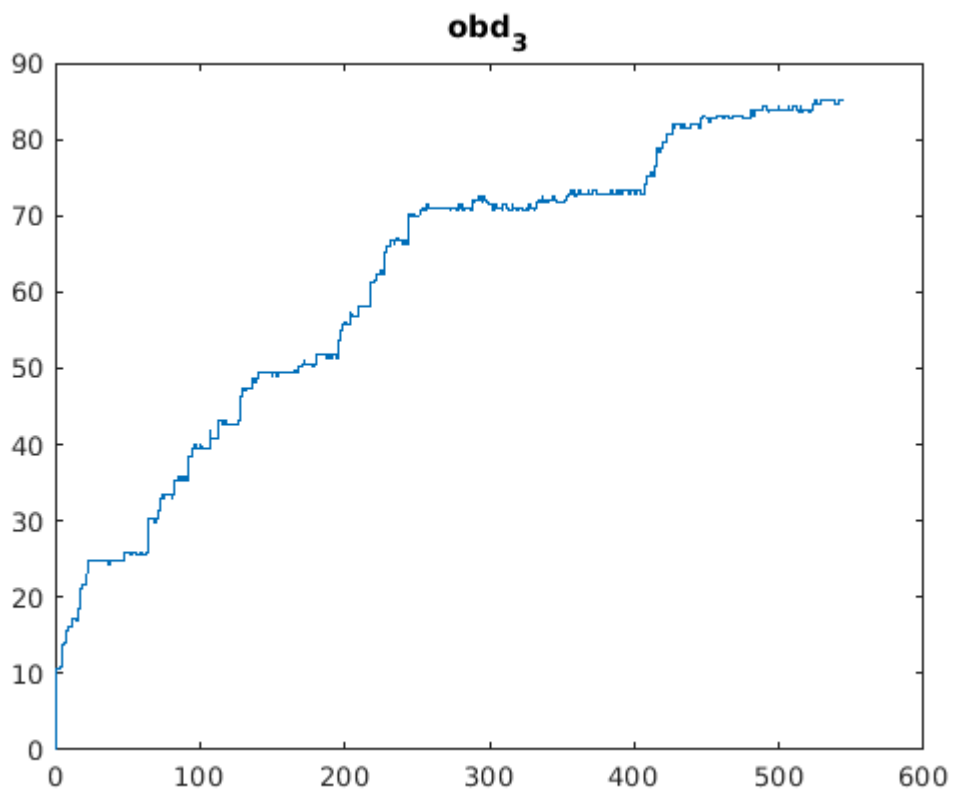
## OBD Plots

```
f7 = figure(7); clf;
```

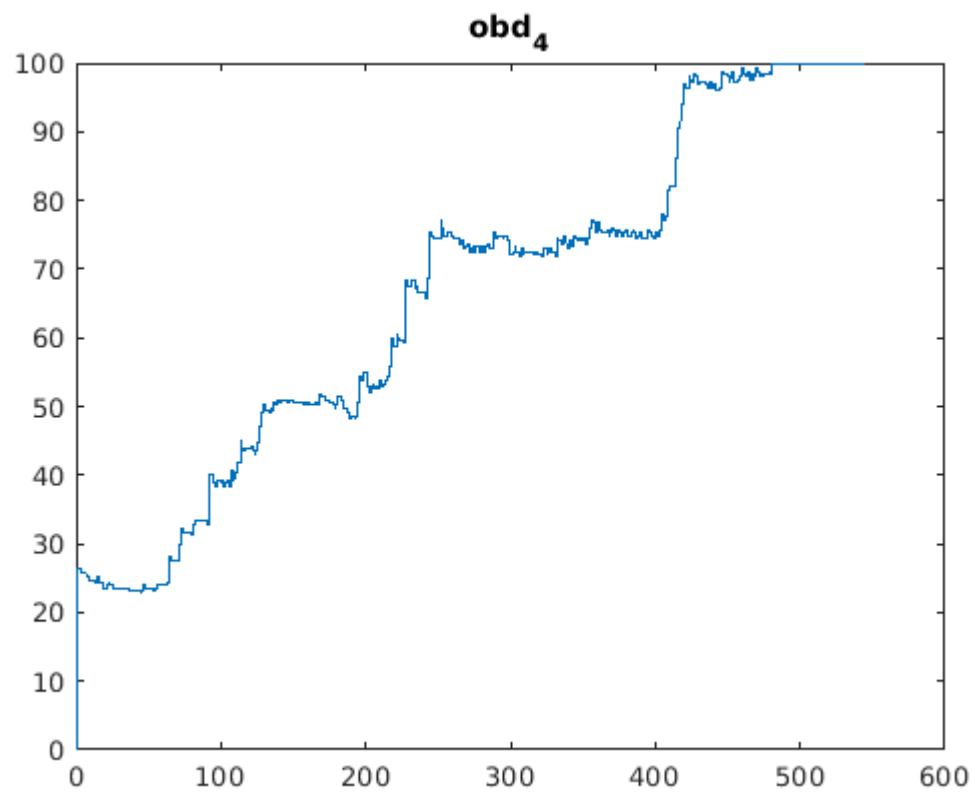
```
plot(obd_t,obd_2);  
title("obd_2");
```



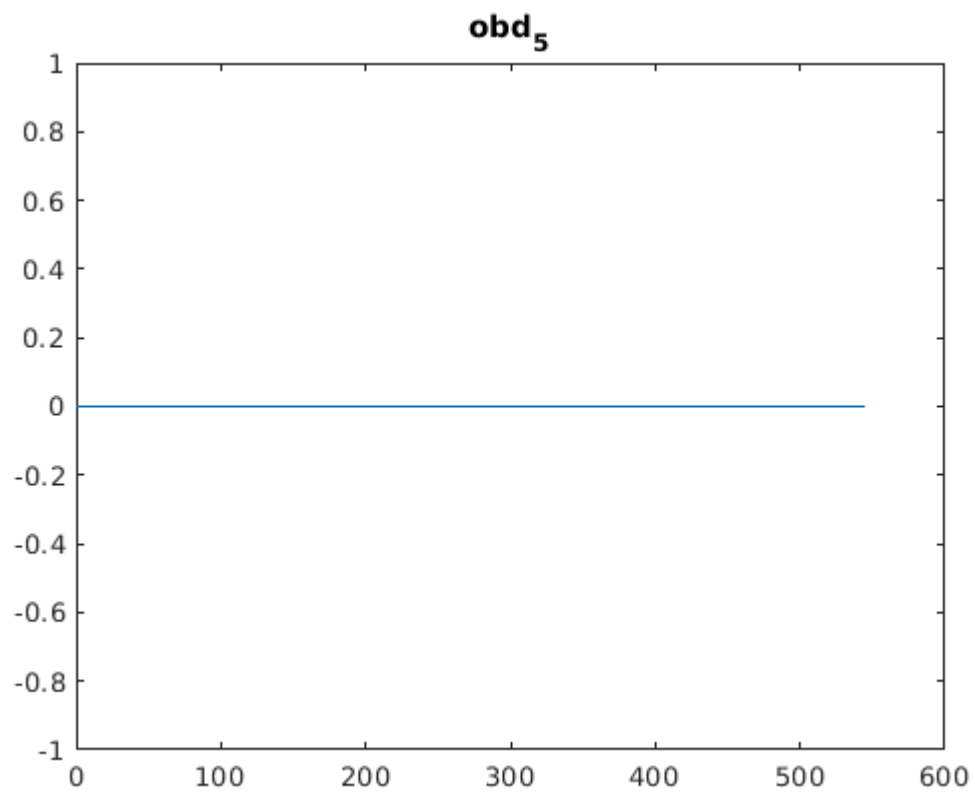
```
f8 = figure(8); clf;  
plot(obd_t,obd_3);  
title("obd_3");
```



```
f9 = figure(9); clf;  
plot(obd_t,obd_4);  
title("obd_4");
```

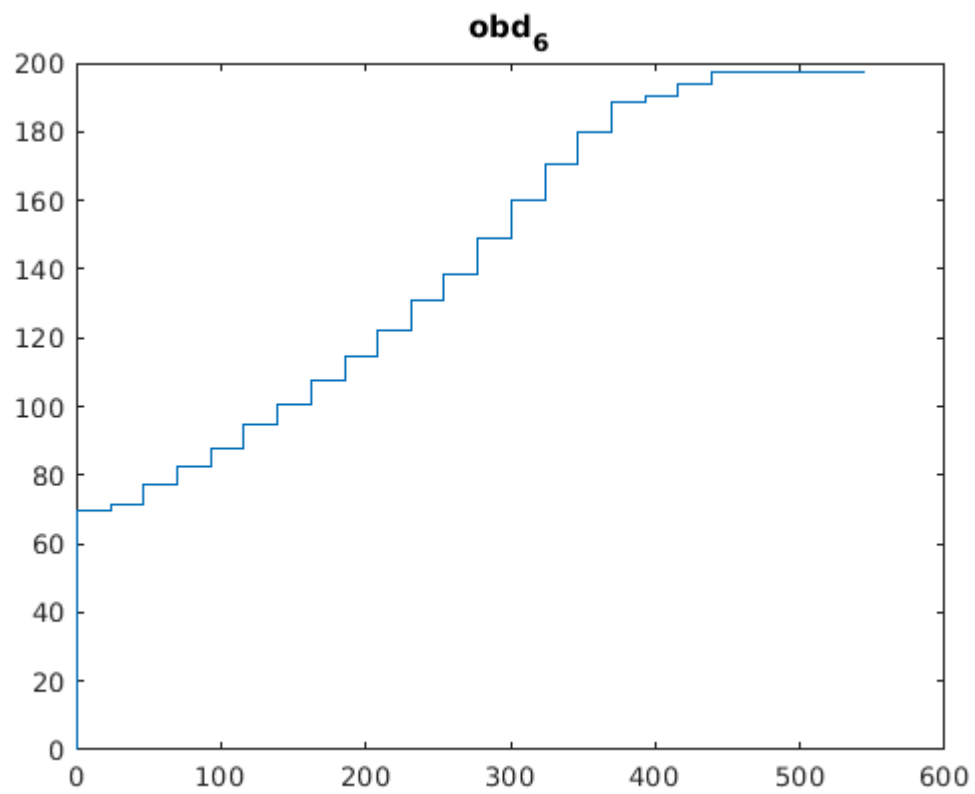


```
f10 = figure(10); clf;  
plot(obd_t,obd_5);  
title("obd_5");
```

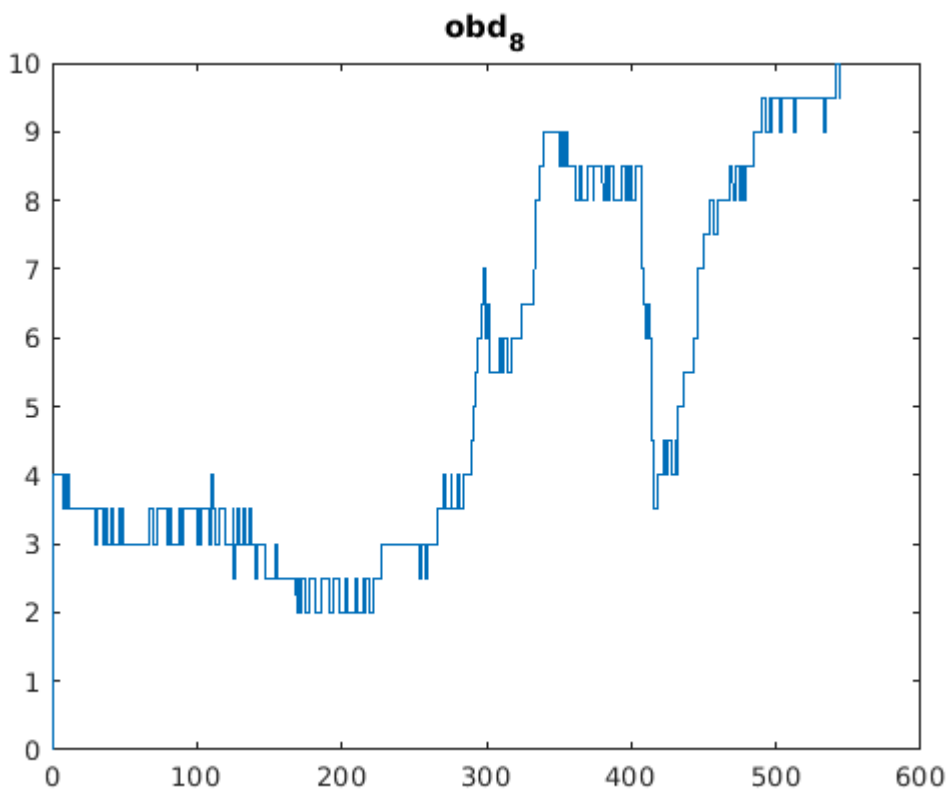


```
f11 = figure(11); clf;  
plot(obd_t,obd_6);  
title("obd_6");
```

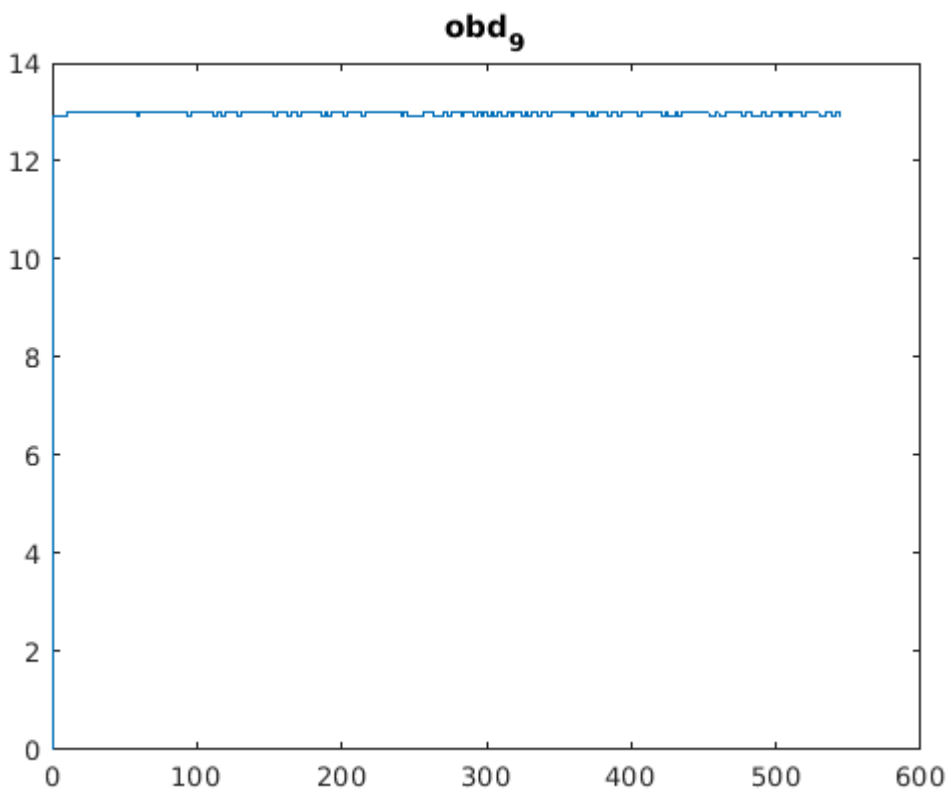




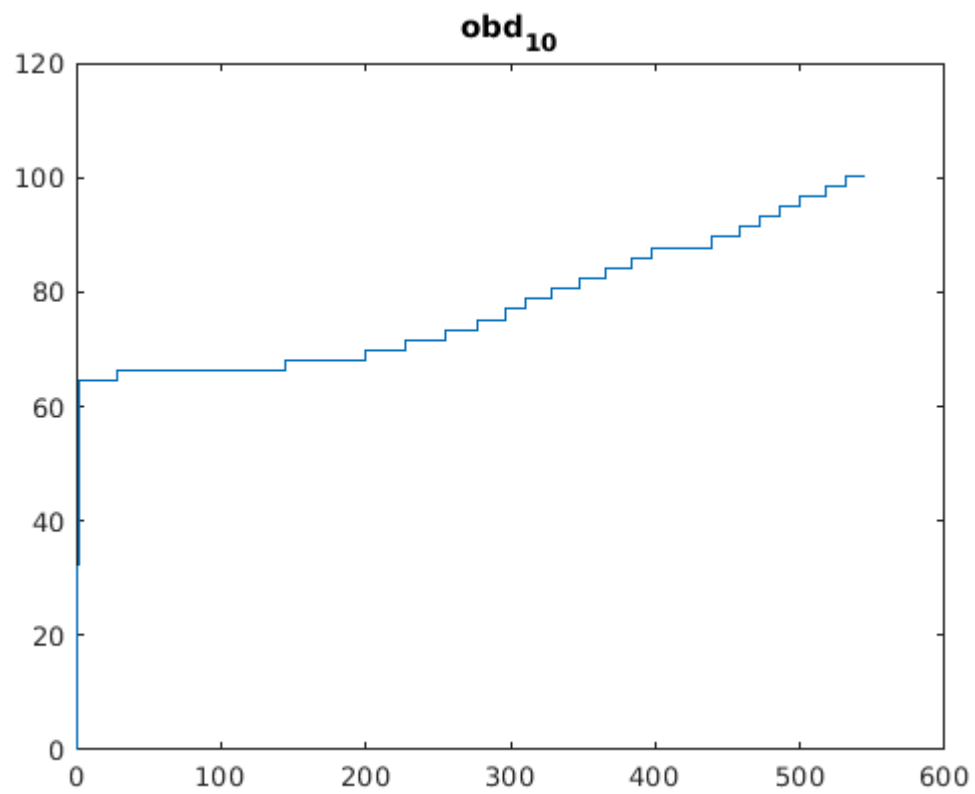
```
f12 = figure(12); clf;  
plot(obd_t,obd_8);  
title("obd_8");
```



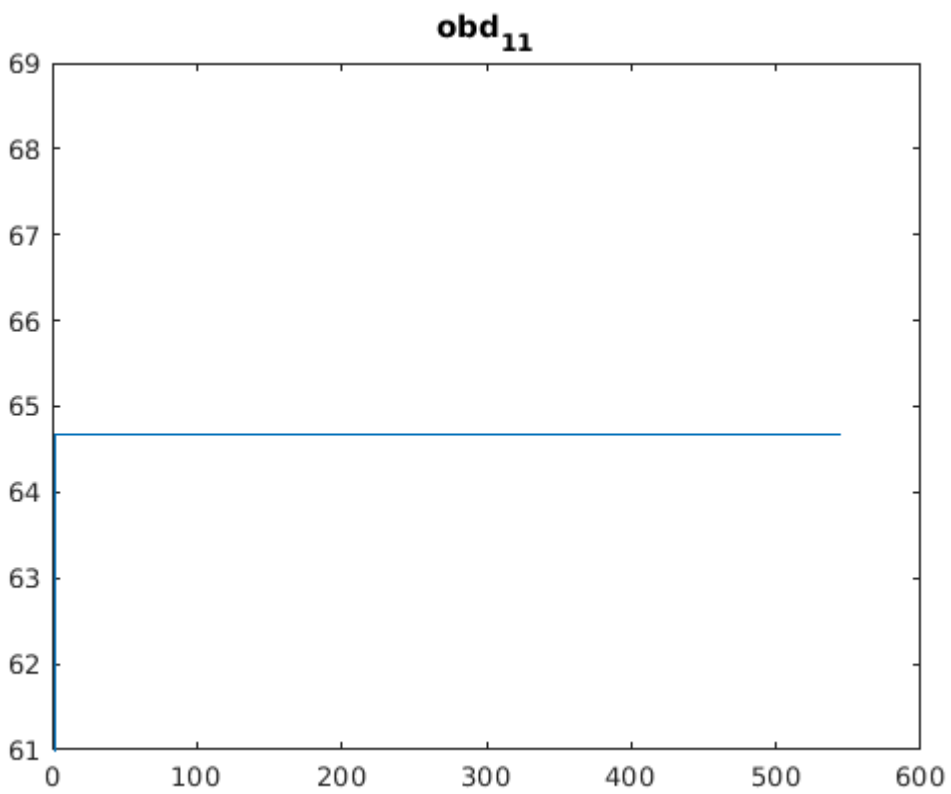
```
f13 = figure(13); clf;  
plot(obd_t,obd_9);  
title("obd_9");
```



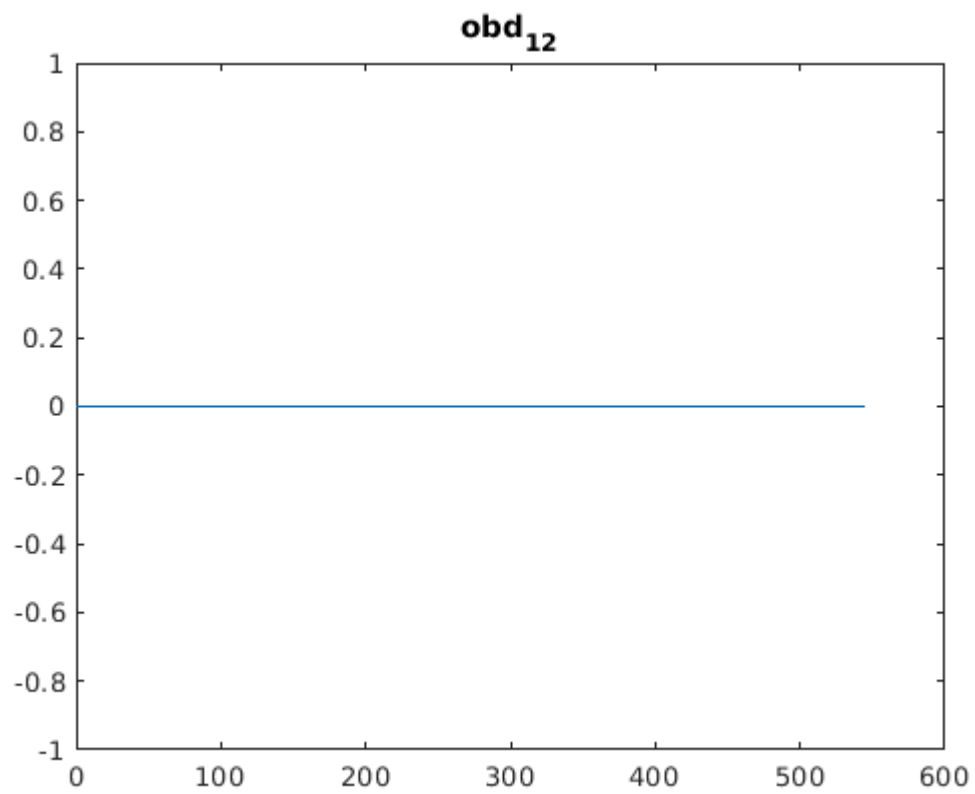
```
f14 = figure(14); clf;  
plot(obd_t,obd_10);  
title("obd_{10}");
```



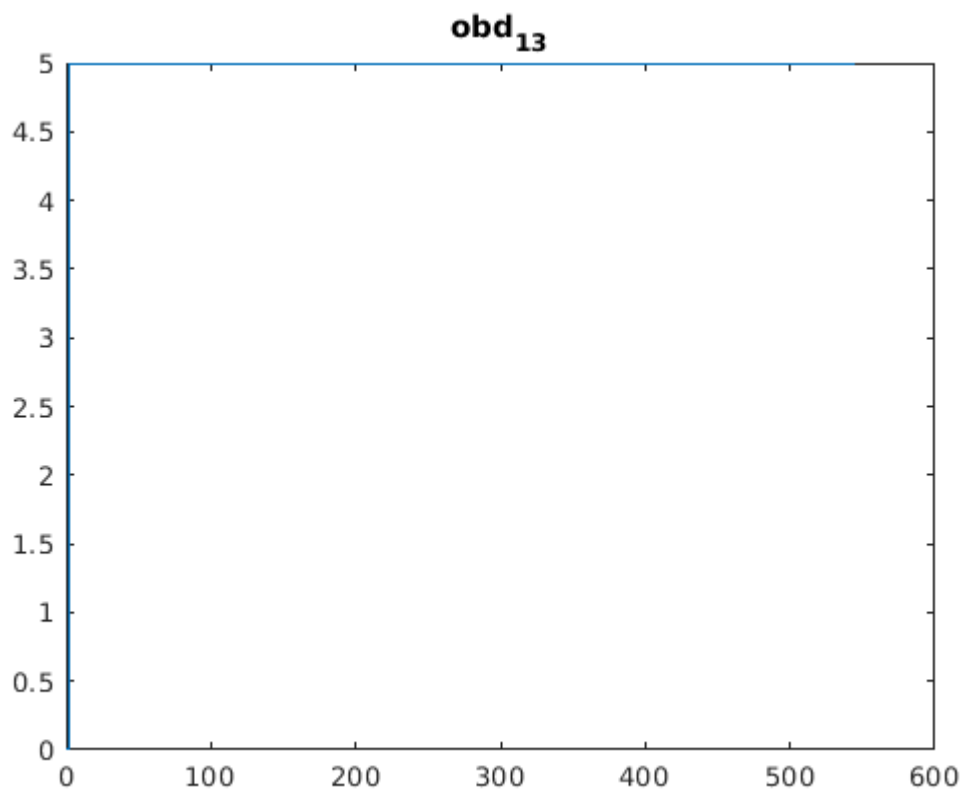
```
f15 = figure(15); clf;  
plot(obd_t,obd_11);  
ylim([61 69]);  
title("obd_{11}");
```



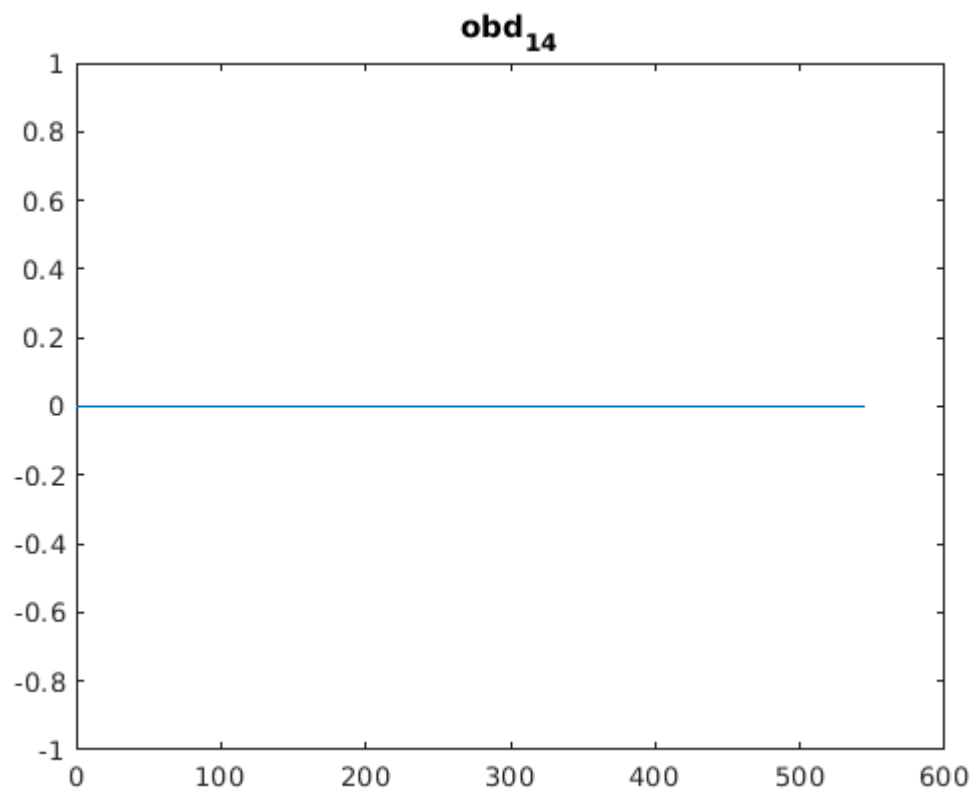
```
f16 = figure(16); clf;  
plot(obd_t,obd_12);  
title("obd_{12}");
```



```
f17 = figure(17); clf;  
plot(obd_t,obd_13);  
title("obd_{13}");
```

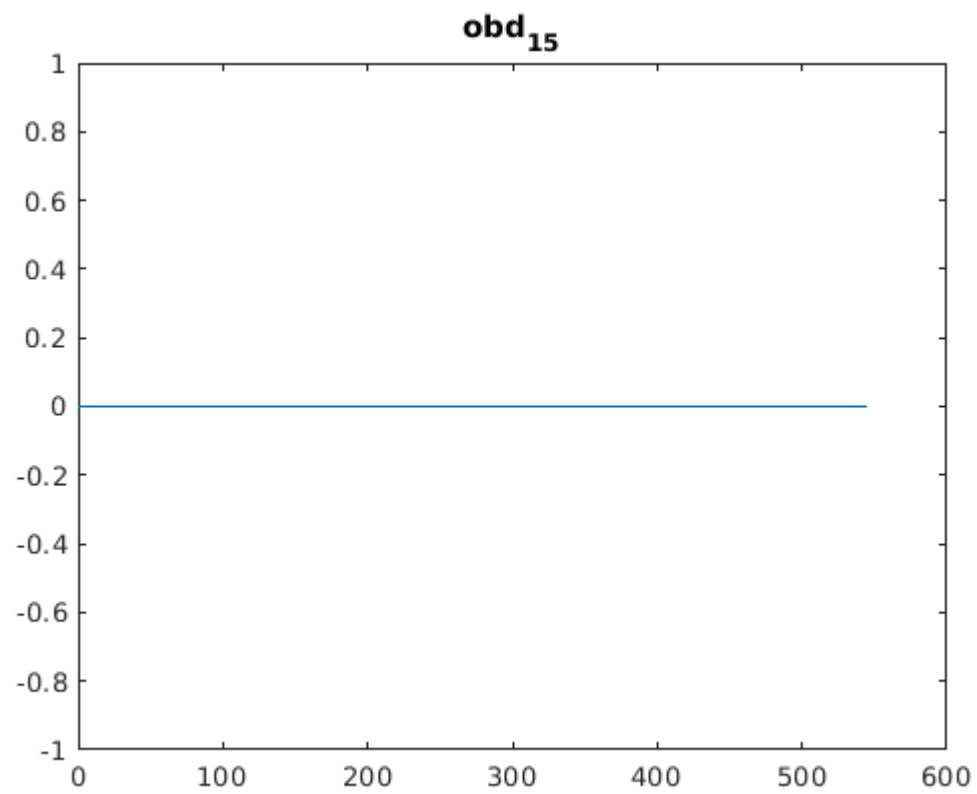


```
f18 = figure(18); clf;  
plot(obd_t,obd_14);  
title("obd_{14}");
```



```
f19 = figure(19); clf;  
plot(obd_t,obd_15);  
title("obd_{15}");
```





```
f20 = figure(20); clf;  
plot(obd_t,obd_16);  
title("obd_{16}");
```

