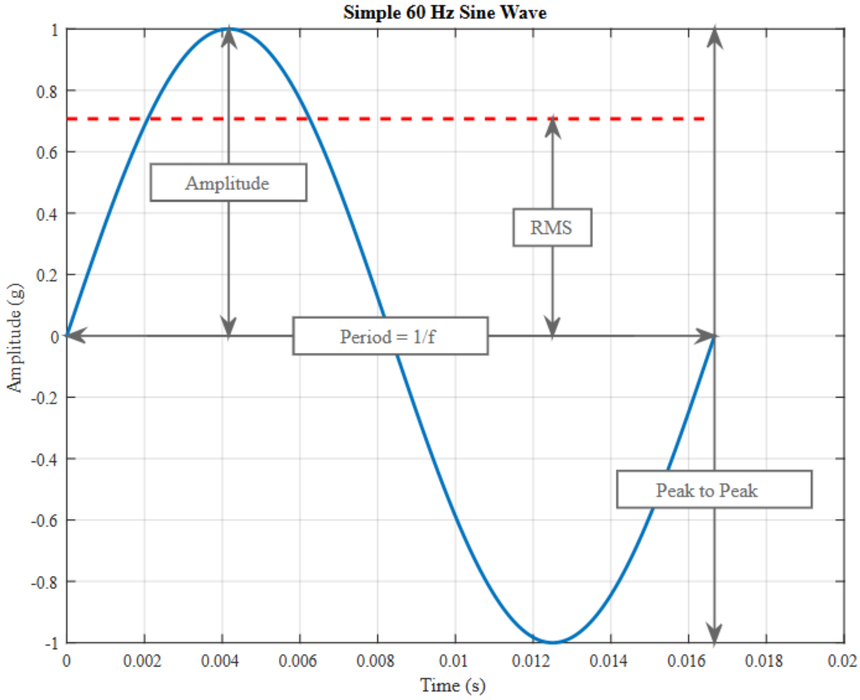
Vibration data profile



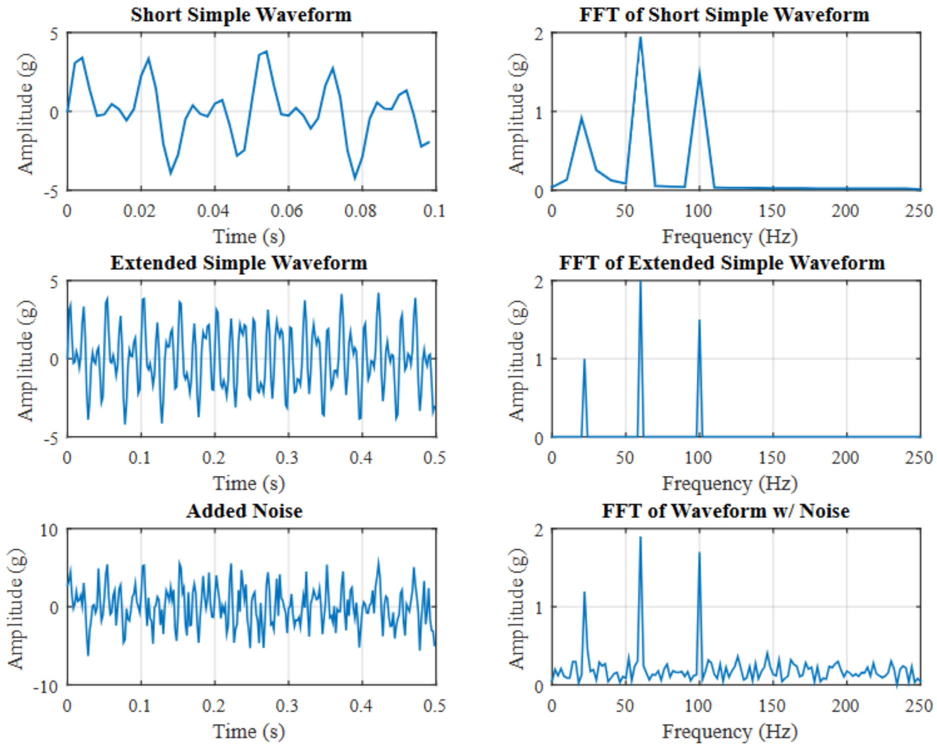
The **RMS** value is generally the most useful parameter because it is directly related to the energy content of the vibration profile and thus the destructive capability of the vibration. RMS also takes into account the time history of the wave form.

For simple sine waves the vibration frequency could be determined by looking at the waveform in the time domain; but as we add different frequency components and noise, we need to perform spectrum analysis to get a clearer picture of the vibration frequency.

Fourier analysis yields acceleration/vibration amplitude as a function of frequency, which lets us perform vibration analysis in the *frequency domain* (or spectrum) to gain a deeper understanding of our vibration profile. A discrete Fourier transform (DFT) multiplies the raw waveform by sine waves of *discrete* frequencies, a fast Fourier transform (FFT) is a DFT using a more efficient algorithm that takes advantage of the symmetry in sine waves.

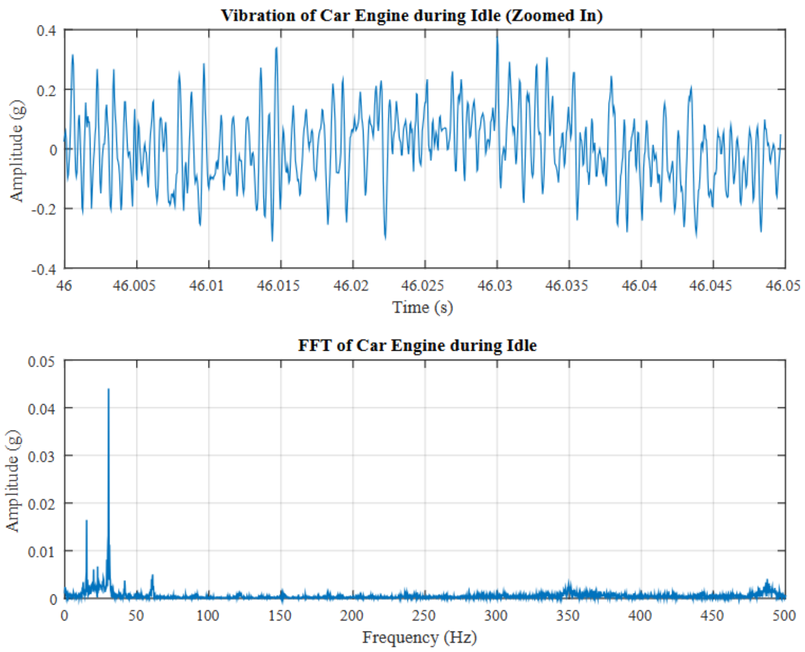
The lowest frequency tested is 0 Hz, the DC component; and the highest frequency is the Nyquist frequency ($F_s/2$). Windowing can be used to scale the frequency range of interest and manipulate the frequency bin width. F_s is the sample rate of the raw waveform.

The frequency bin width is inverse of the total acquisition time. The number of discrete frequencies that are tested as part of a Fourier transform is directly proportional to the number of samples in the original waveform, with N being the length of the signal, number of frequency bins is equal to N/2.



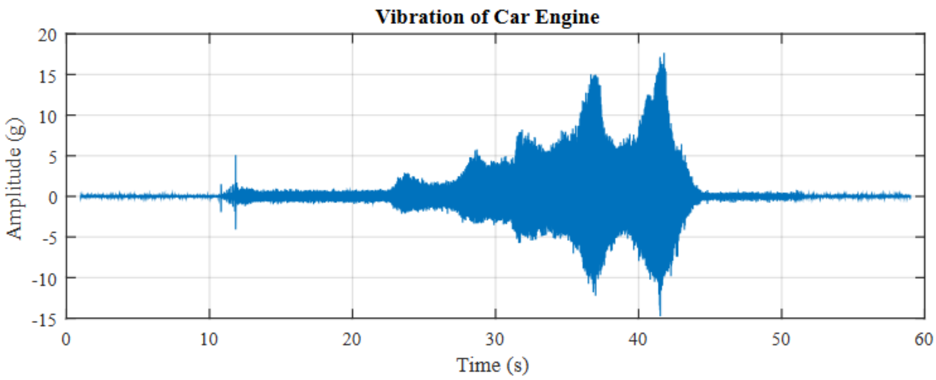
1) From FFT, we see the waveform consists of 3 frequency components: 22 Hz, 60 Hz, and 100 Hz.
2) The signal length affects the frequency resolution of the FFT.
3) FFT is able to clearly identify the major frequencies of the waveform.

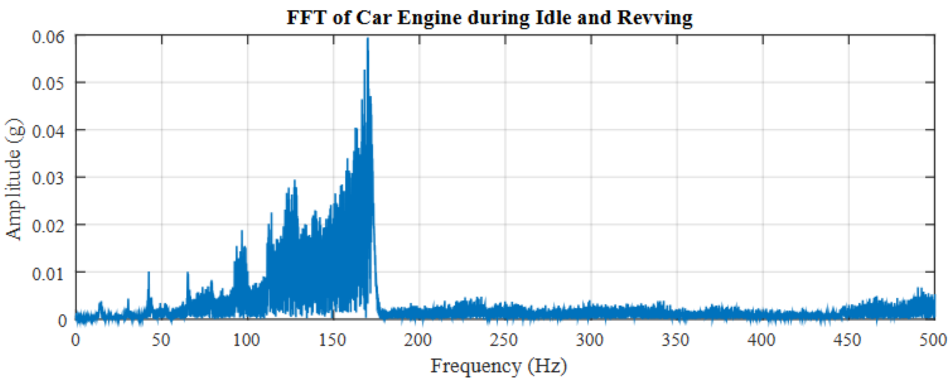
Example



In the FFT there is clearly a dominant frequency at 30 Hz or 1,800 RPM which tells us that at idle the crank shaft is rotating at 900 RPM (or 15 Hz, smaller peak in FFT).

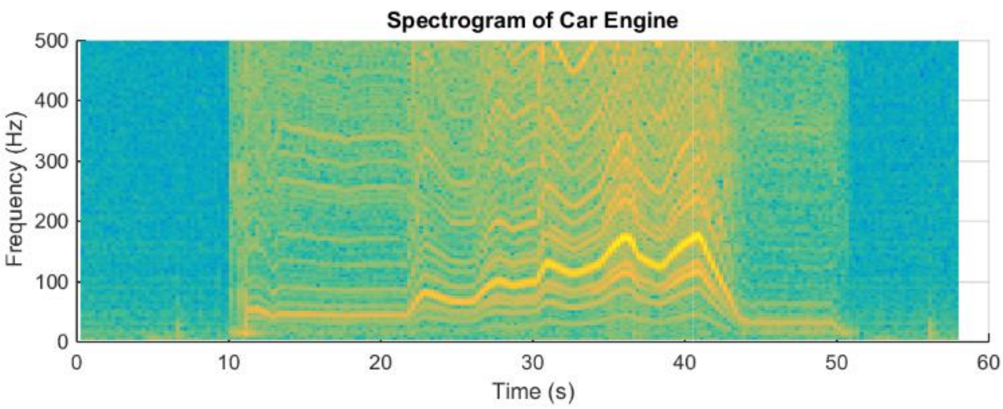
In many applications the vibration frequency will change with time and you can run into trouble if you only look at the FFT. Let's zoom out of the area where the car engine is running at a relatively fixed rate, and compute an FFT of the entire signal. In this test the engine sat off for a period of time, idled, then the engine was revved before letting it idle again and finally turning it off.





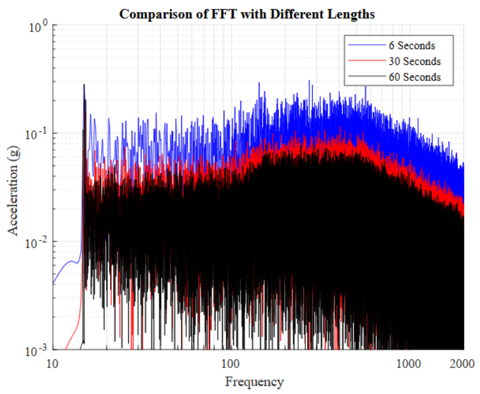
In this example, and others where the vibration frequency changes with time, we need a spectrogram. A spectrogram works by breaking the time domain data into a series of chunks and taking the FFT of these time periods. These series of FFTs are then overlapped on one another to visualize how both the amplitude and frequency of the vibration signal changes with time.

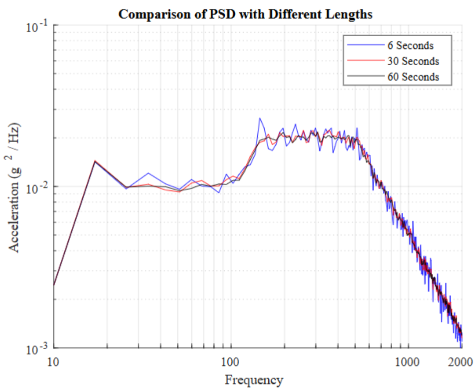
The spectrogram shown below illustrates how the dominate frequencies change with time in relation to when the car engine was idled and revved. Using a spectrogram the analyser gains a much deeper understanding of the vibration profile and how it changes with time.



FFTs are great at analysing vibration when there are a finite number of dominant frequency components; but a **power spectral density (PSD)** is used to characterize random vibration signals. With PSD, we can compare vibration levels in signals of different lengths.

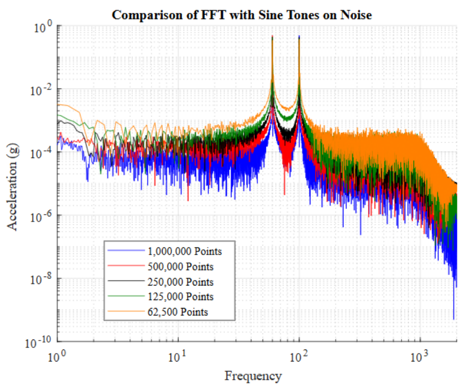
Check out how the longer the time series is (and the finer the frequency bin width is), the lower the amplitude of the FFT becomes! This means you can't really use FFTs to compare and quantify vibration environments.

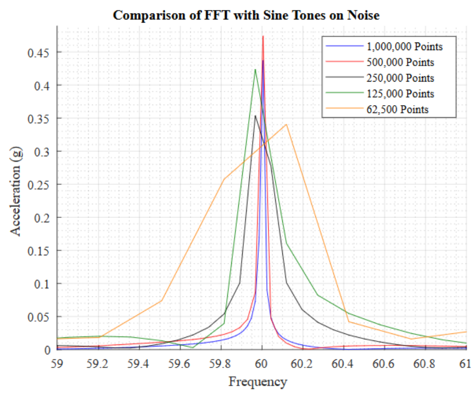


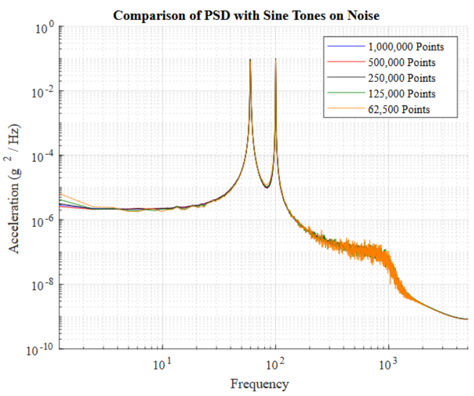


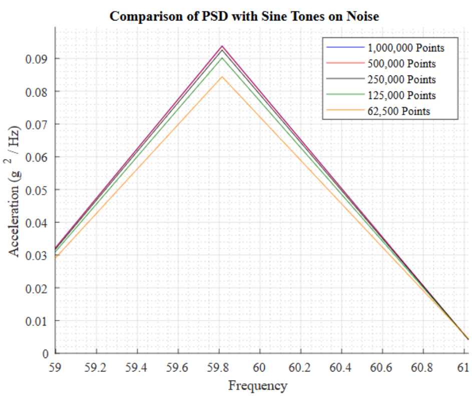
In this plot I've kept the frequency bin width the same at 8 Hz. These different time lengths do nothing to the amplitude of the resulting PSD because they are normalized to the bin width.

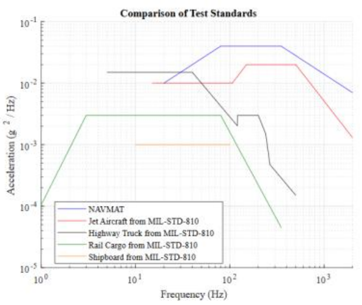
There're some applications where there are very specific frequencies contributing to the signal such as when looking at machinery with rotating equipment.

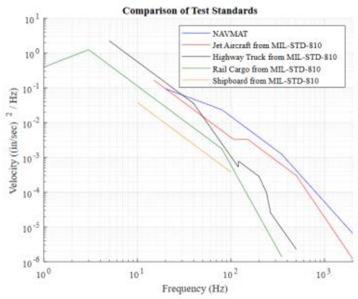


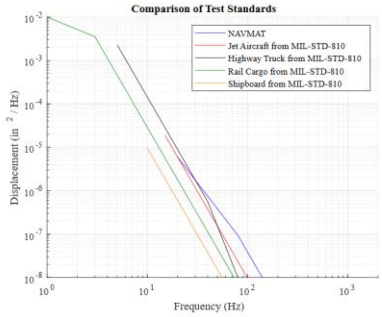






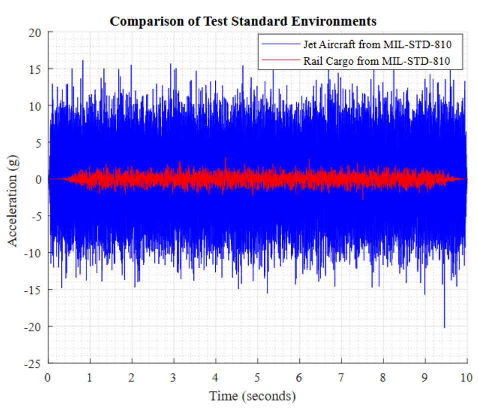


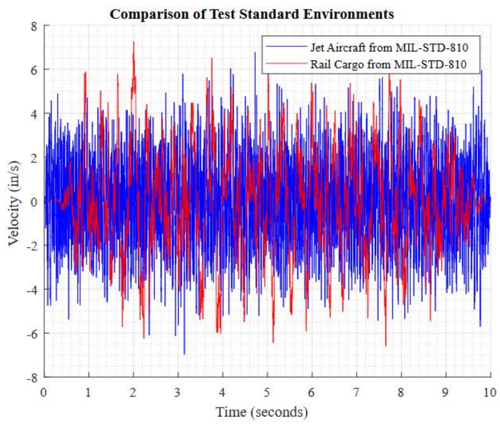




The vibration environment for rail cargo looks less severe than the jet environment. But by recognizing the lower frequency density of the rail environment, you can predict it will introduce higher velocities and displacements than the jet environment. Not all frequencies can be treated equally!

Back to time domain:





One would say that the jet aircraft has a more severe environment, but when we look at the velocity environment, they have a similar amplitude. And kinetic energy is proportional to velocity squared, so we should arguably be more concerned with this when worried about fatigue. When we convert to displacement we can see just how much "stronger" that rail environment is!