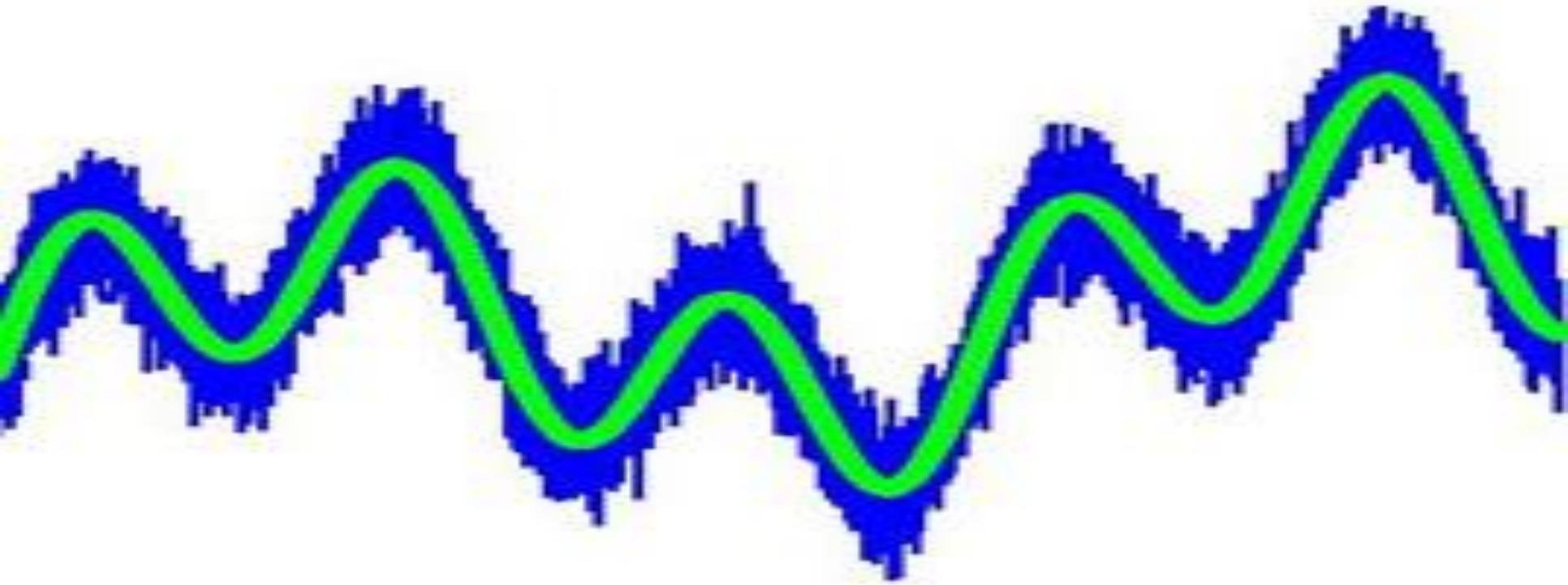


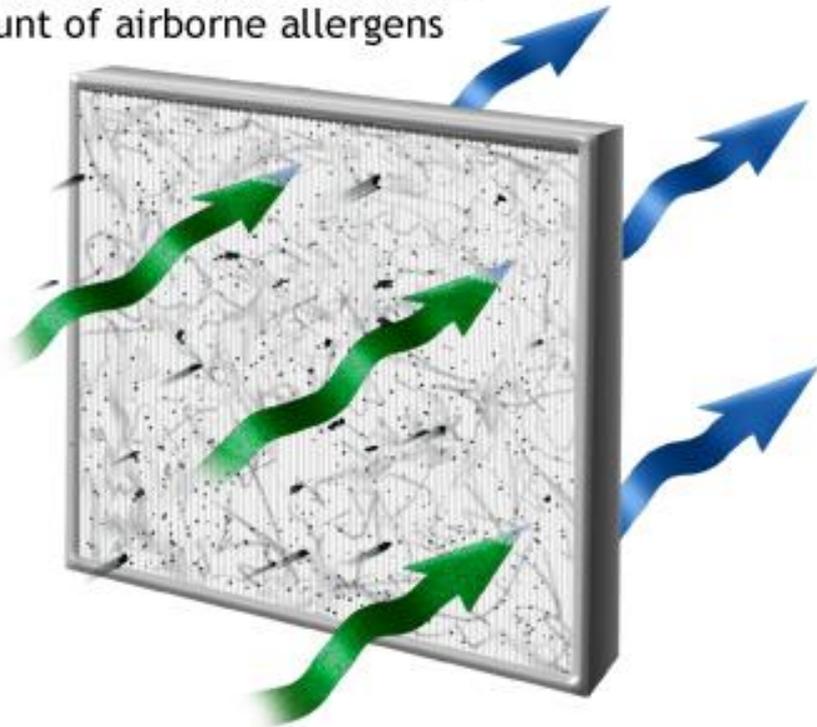
Filtering

Separating **what you want** from **what you have**





A HEPA air filter can reduce the amount of airborne allergens



Signals are all around us

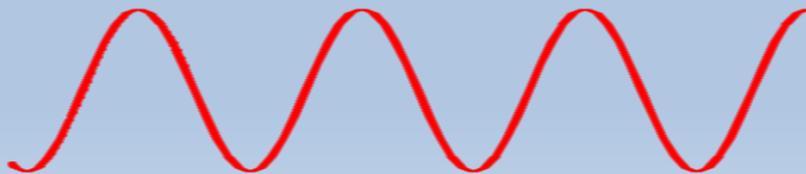
- Image, video, audio, radio, medical and musical signals...
- These signals contain a lot of information



We can also filter *signals*



signal (we want)
+
noise (we don't)



signal (we want)

Digital Filters

When an image is being processed by a computer/iPhone...

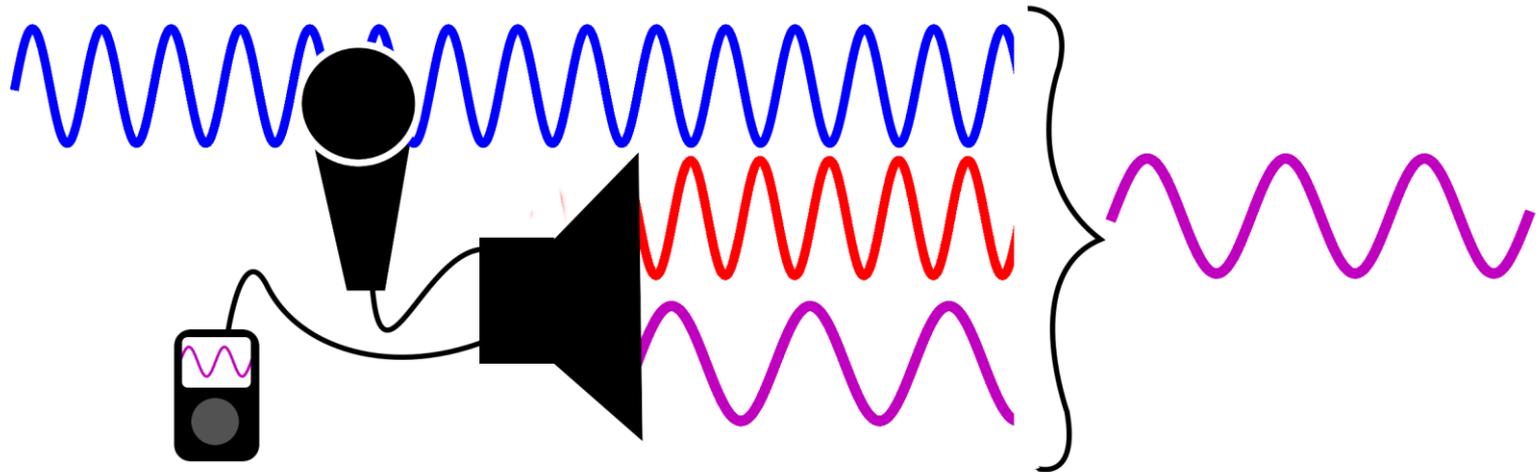
```
1 0 0 1 0 1 0 0 0 1 0 1 0 0 1 0 1 0 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1
0 0 0 1 0 1 0 0 1 0 1 0 1 0 1 0 1 0 0 0 0 1 0 0 1 0 1 0 0 0 1 0 1
0 0 1 0 1 0 1 0 1 0 0 1 0 1 0 1 0 1 0 0 0 0 1 1 1 1 1 0 0 0 0 1 1
0 1 1 1 1 0 0 0 0 1 0 1 0 1 1 1 1 0 0 0 0 1 1 1 0 1 0 1 0 0 1 0 1
0 1 0 1 0 1 0 1 0 0 1 0 0 1 1 0 0 1 1 1 0 0 0 1 1 1 1 0 1 0 1 0 0
```

...we can filter it using computation
(also known as digital signal processing or DSP)

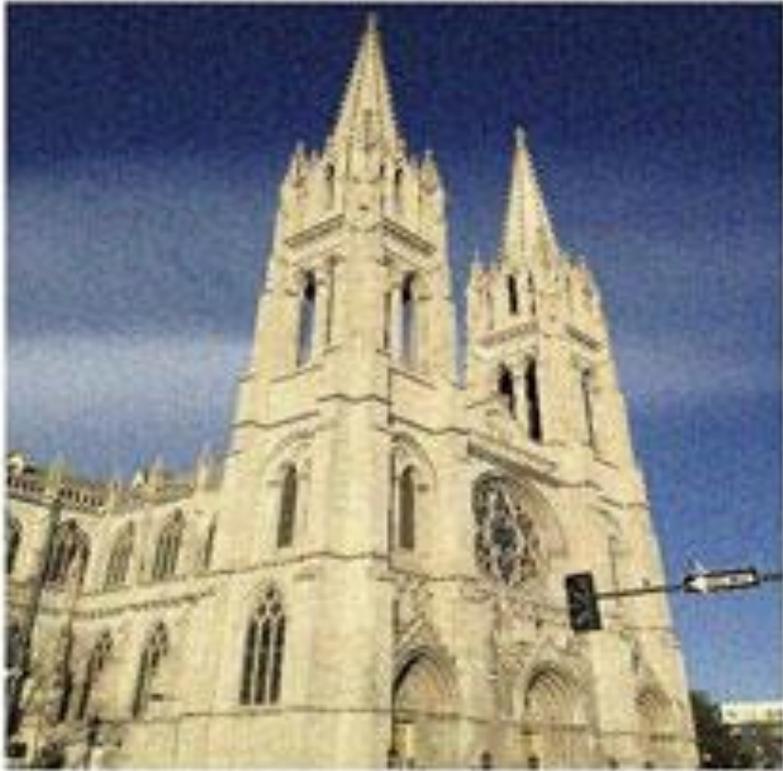
What can filtering achieve?



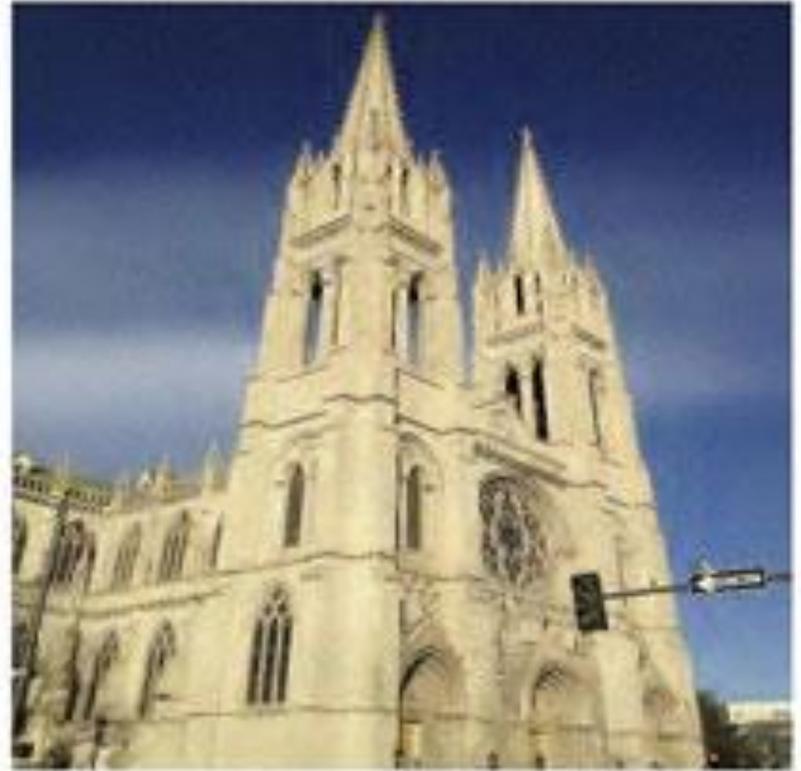
Noise-cancelling headphones reduce unwanted ambient sounds (**noise**) by generating an **antinoise** sound wave to cancel the noise, letting just the **music** be heard



What can filtering achieve?



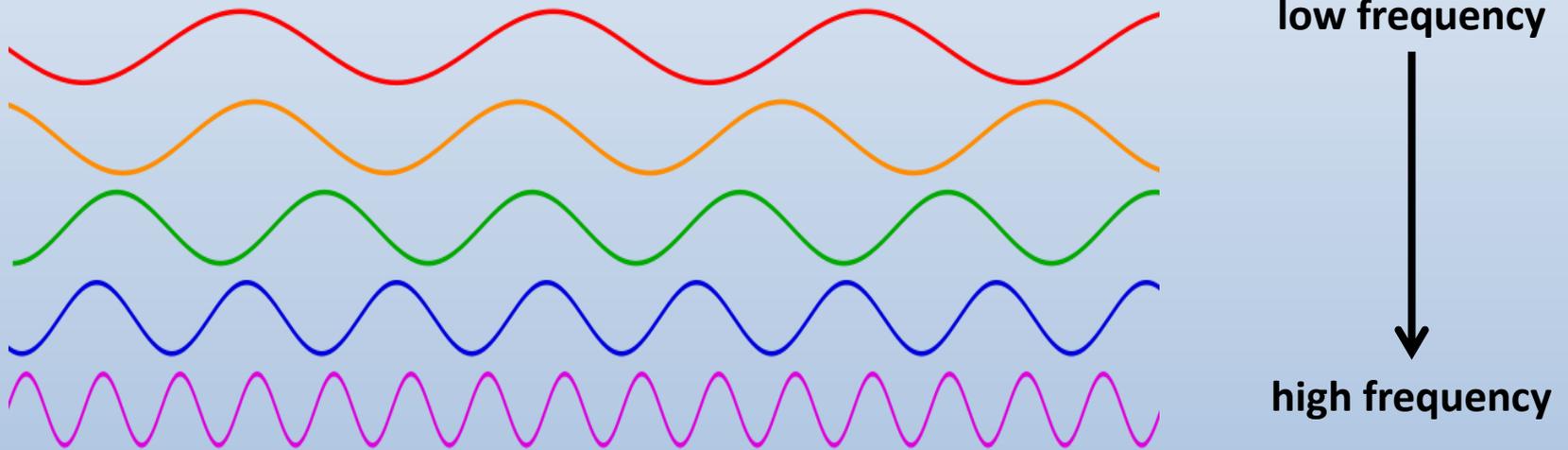
noisy image



de-noised image

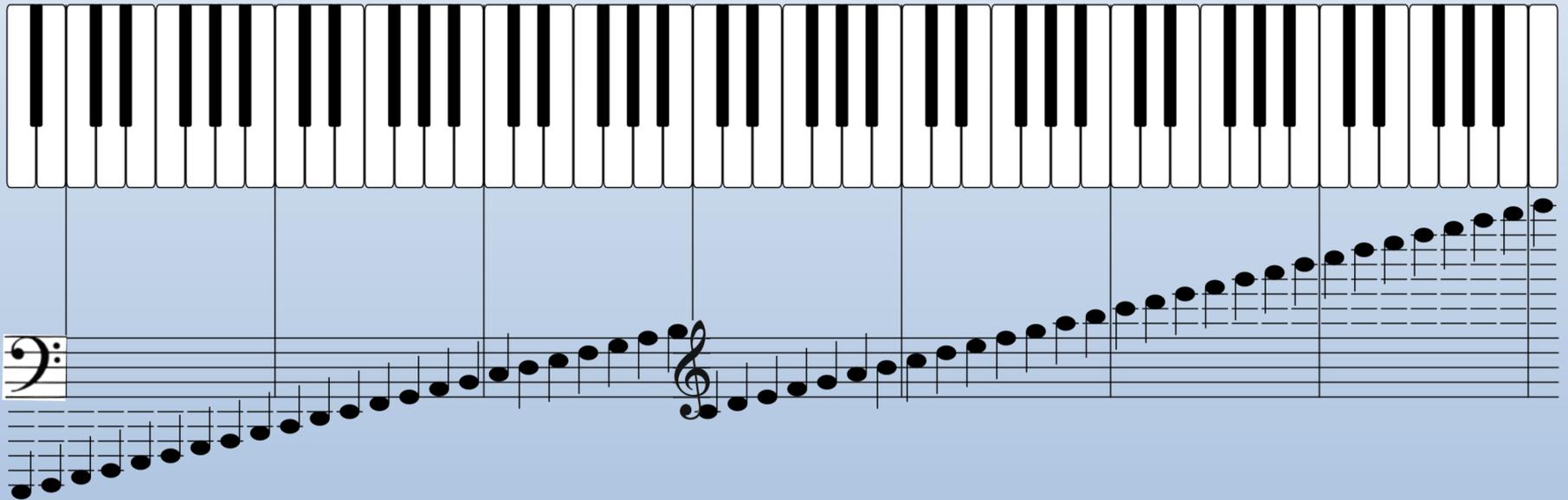
The concept of *frequency*

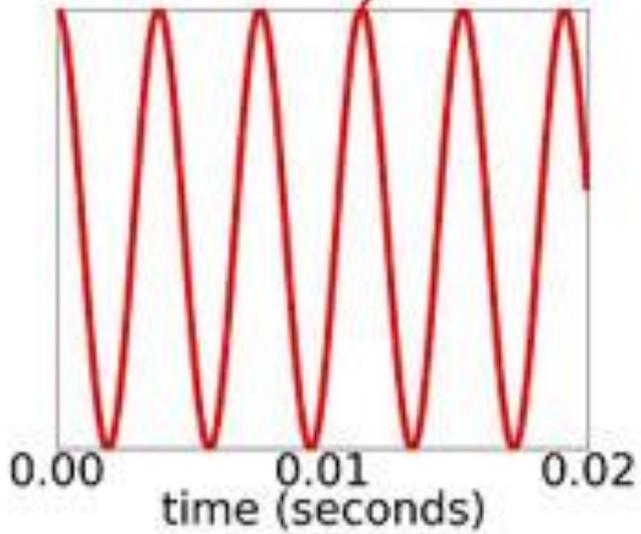
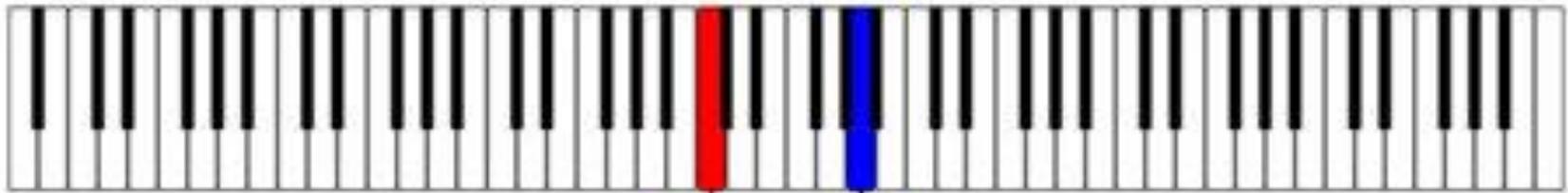
- Describes how quickly a signal moves



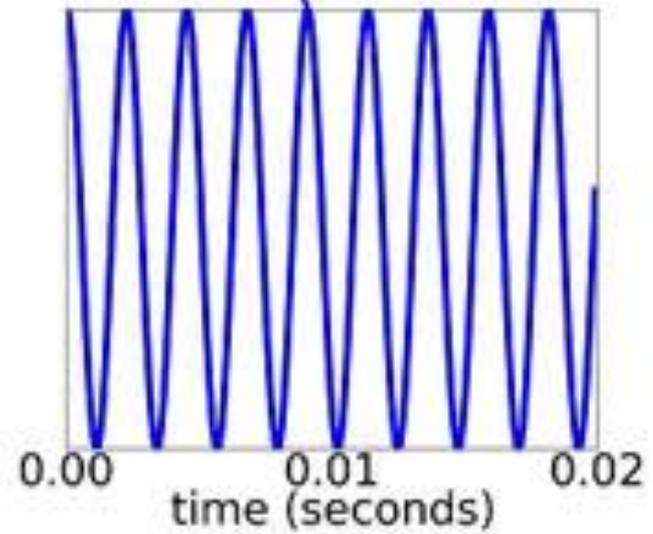
- Plays an important role in many types of filters

Frequency in music



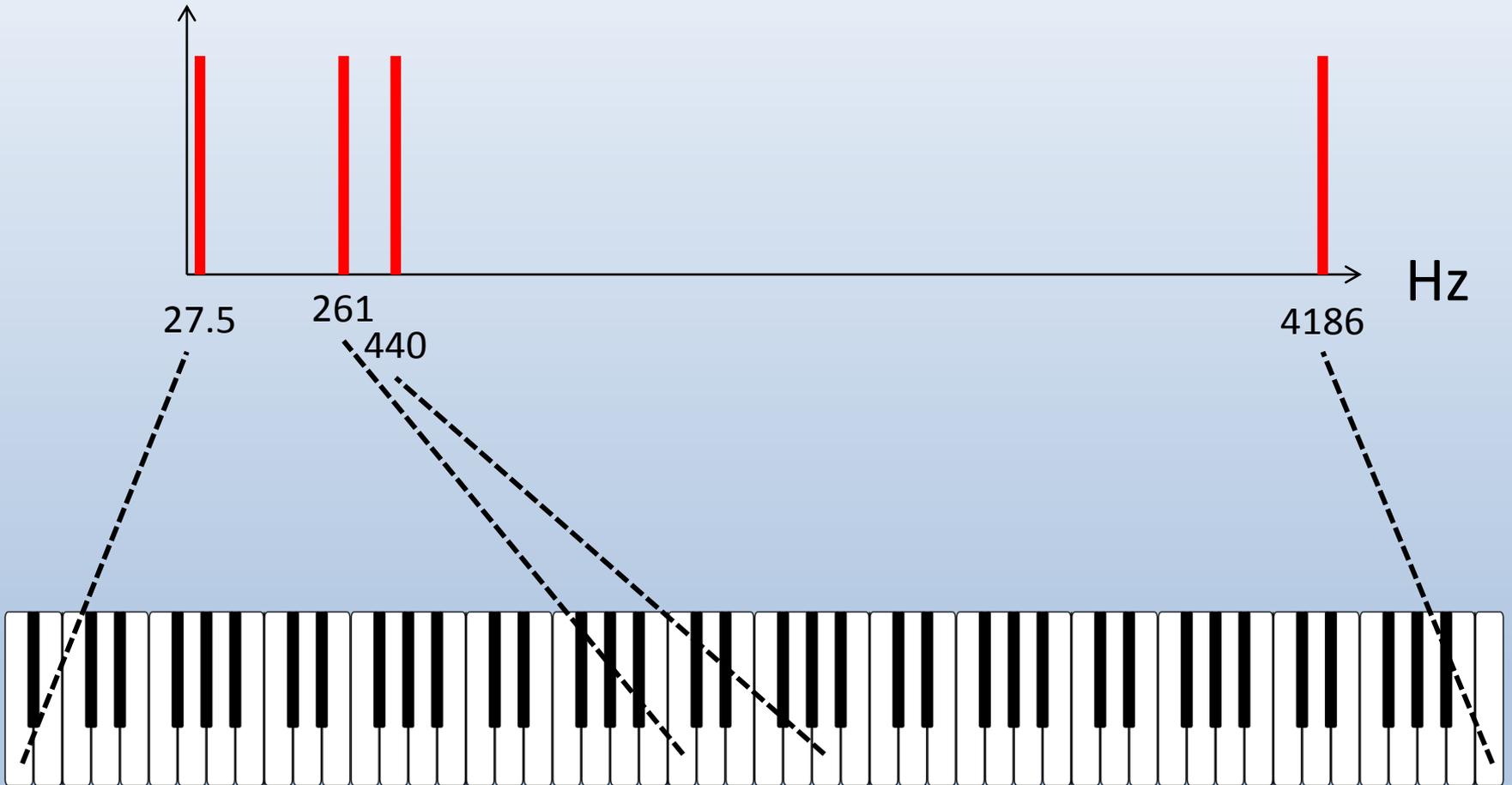


middle C
261.626 Hz

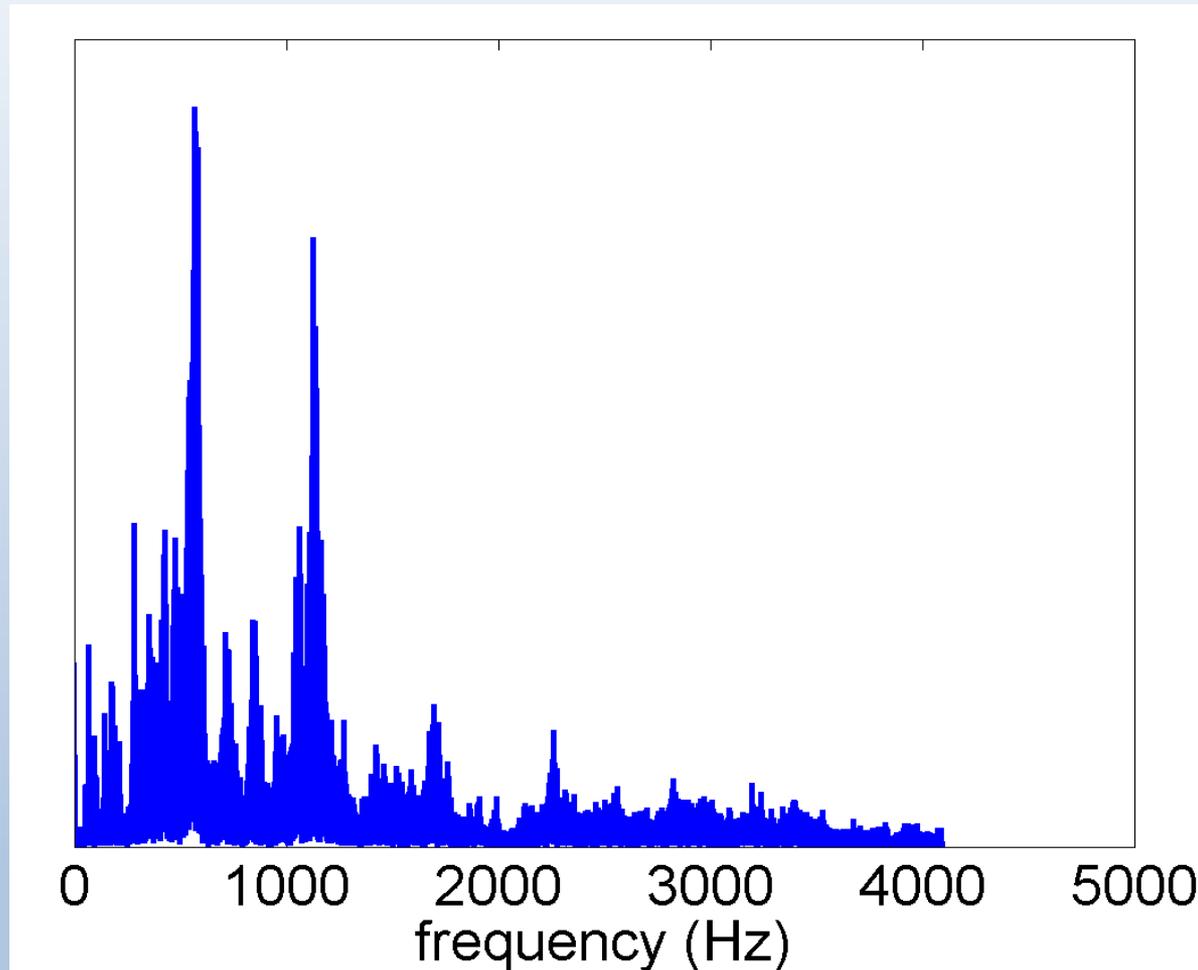


middle A
440 Hz

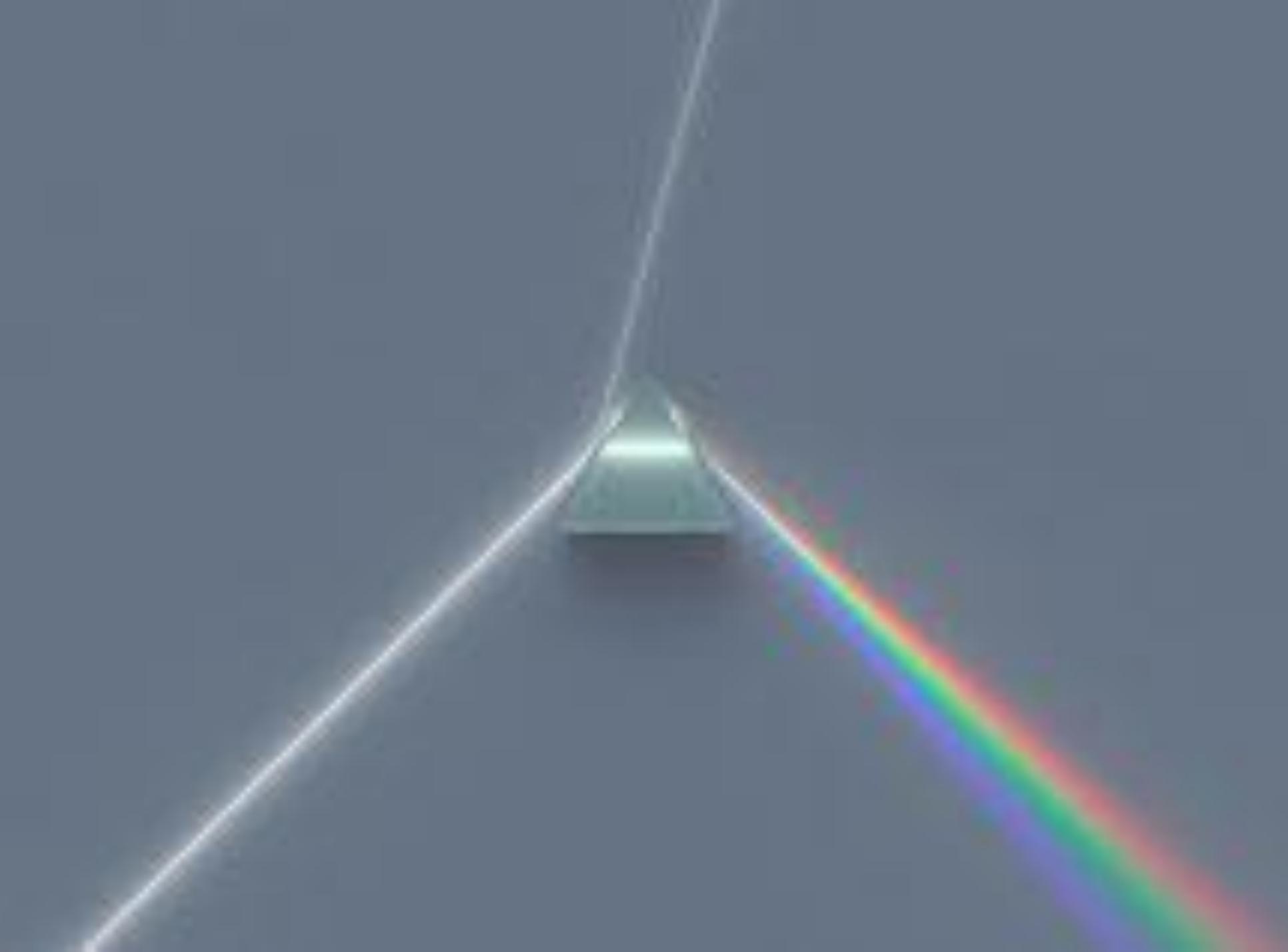
Spectrum



Spectrum of a “real-world” signal



Real-world signals can be thought of as *combinations* of different frequency components



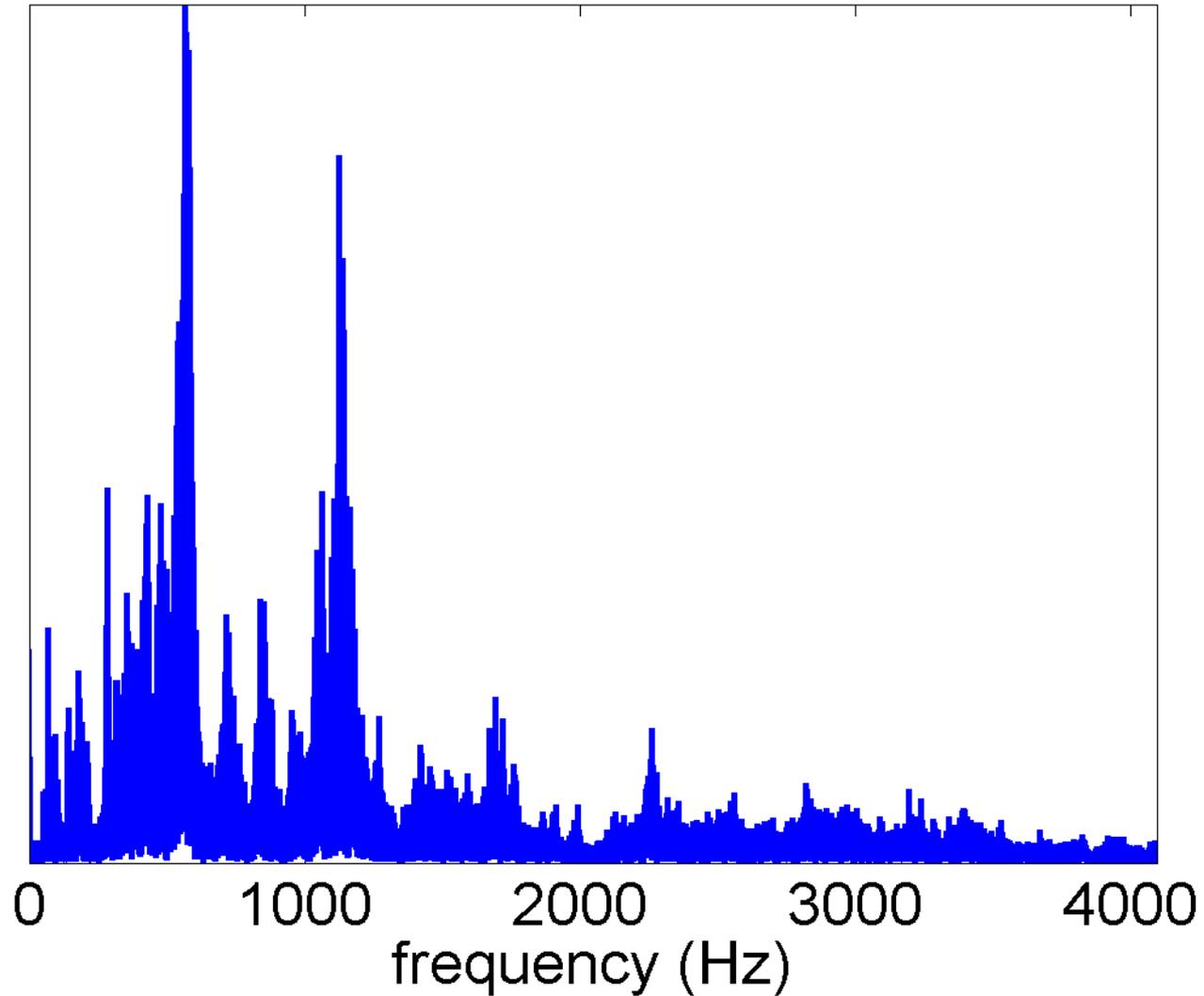


Many **filters** act by

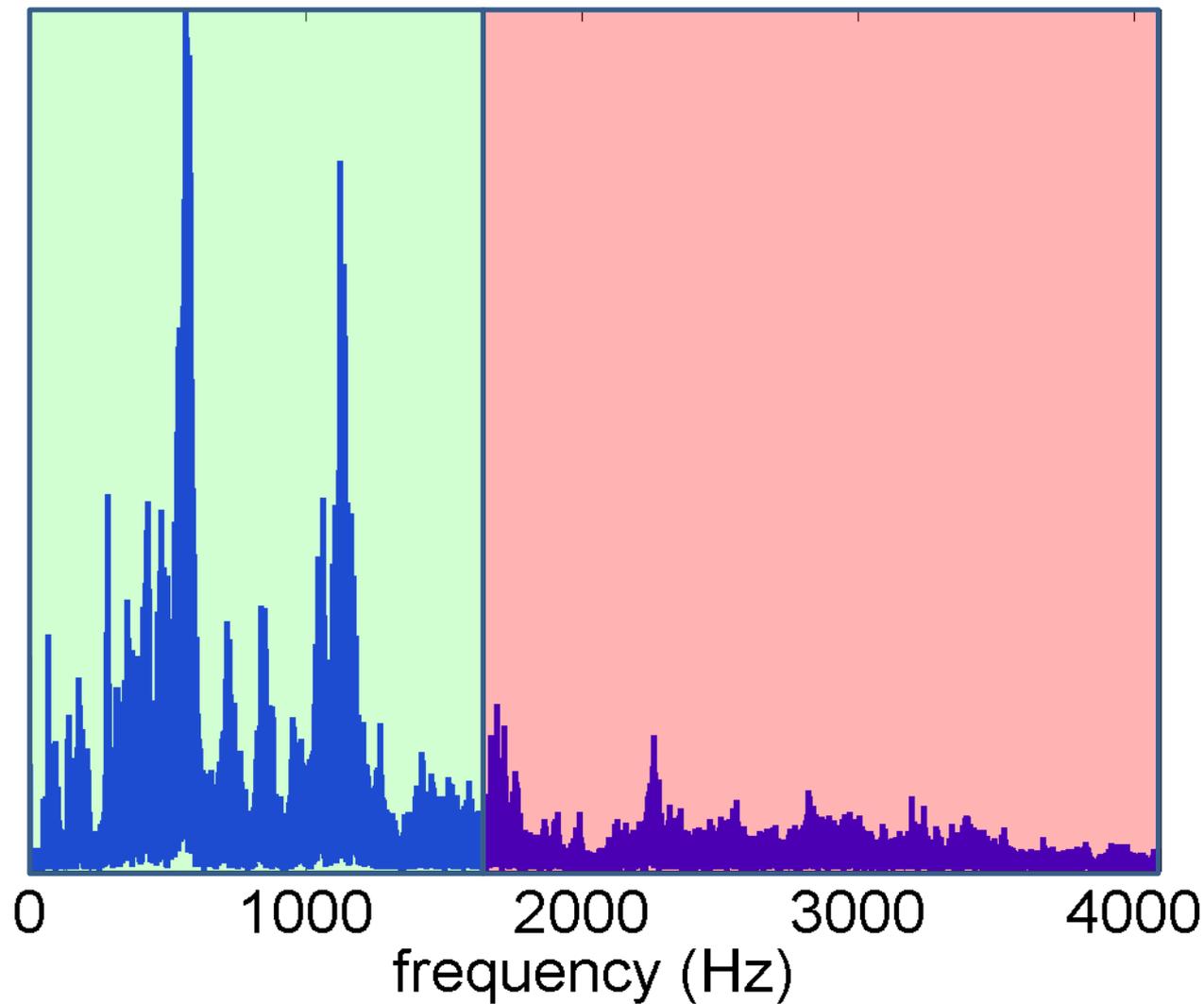
keeping some frequencies (the ones we want)

and throwing away others (the ones we don't)

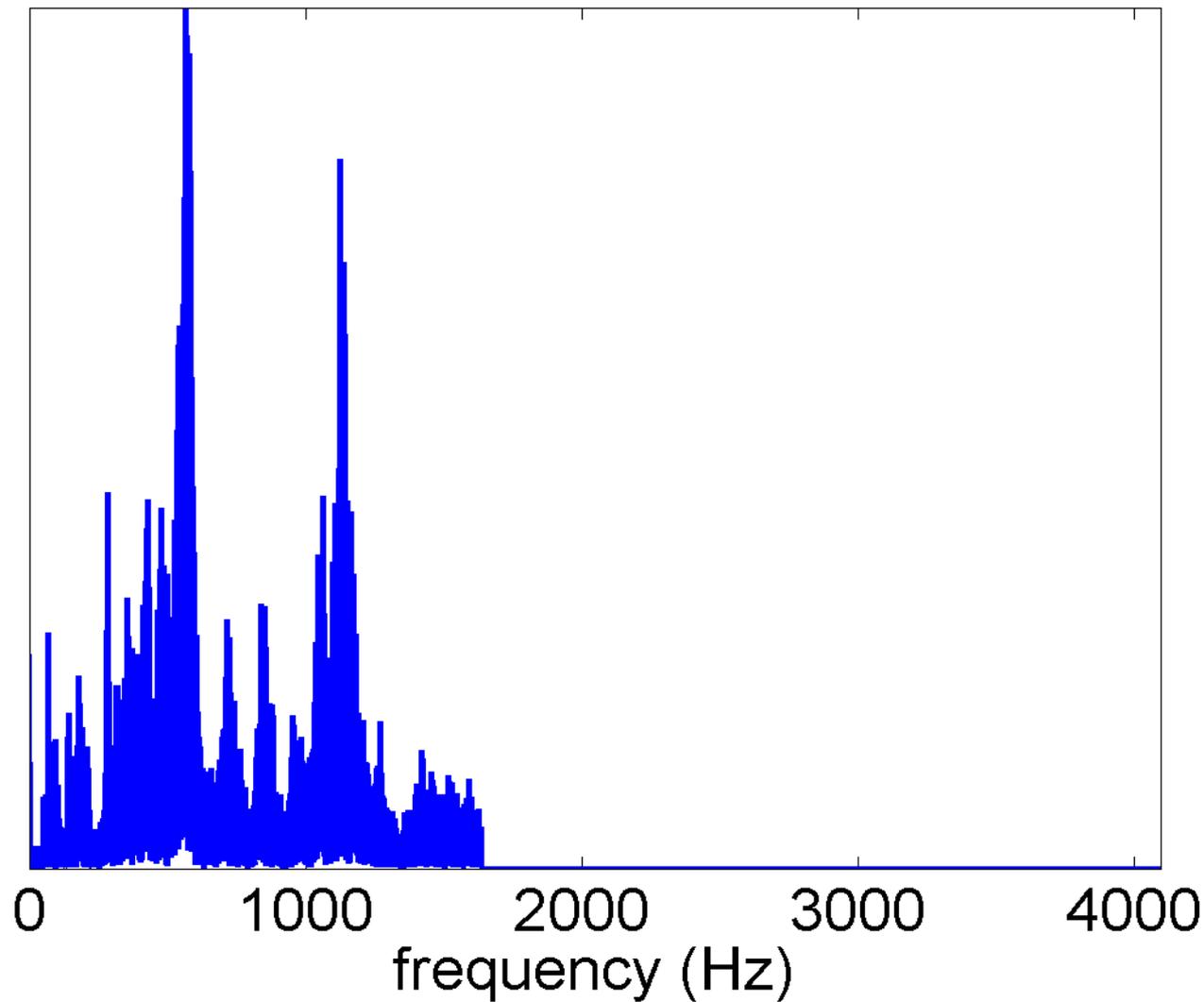
Low-pass filter



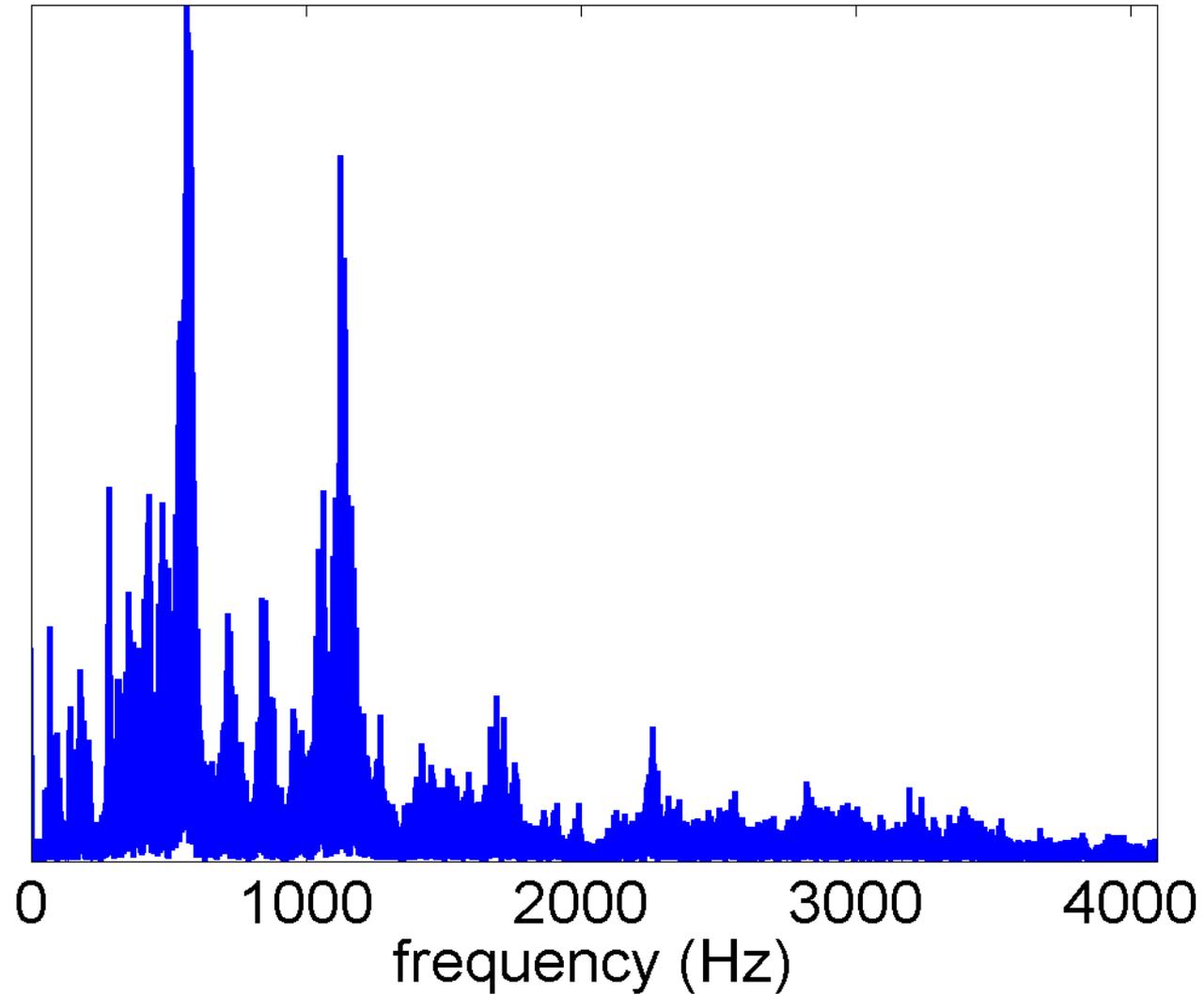
Low-pass filter



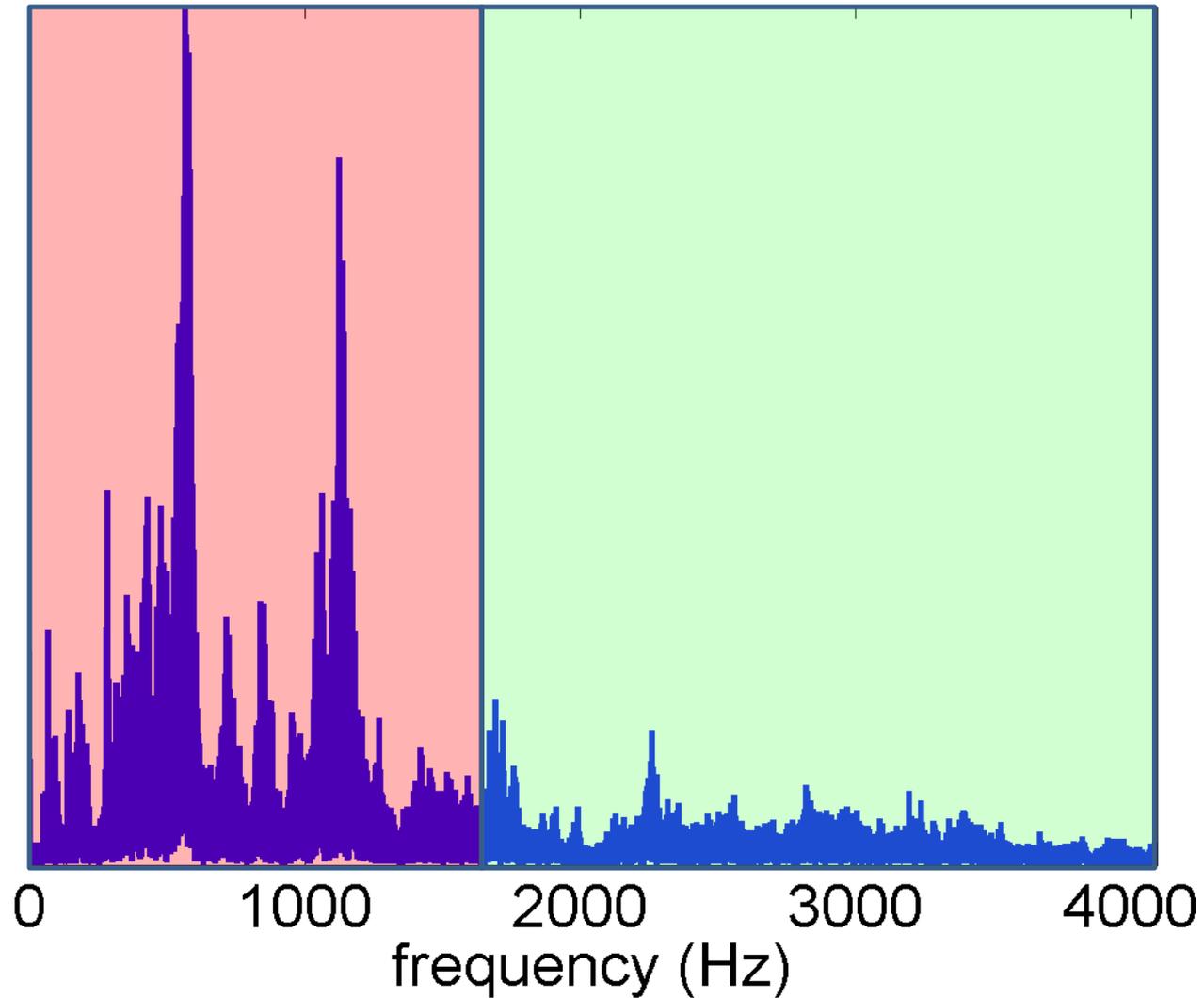
Low-pass filter



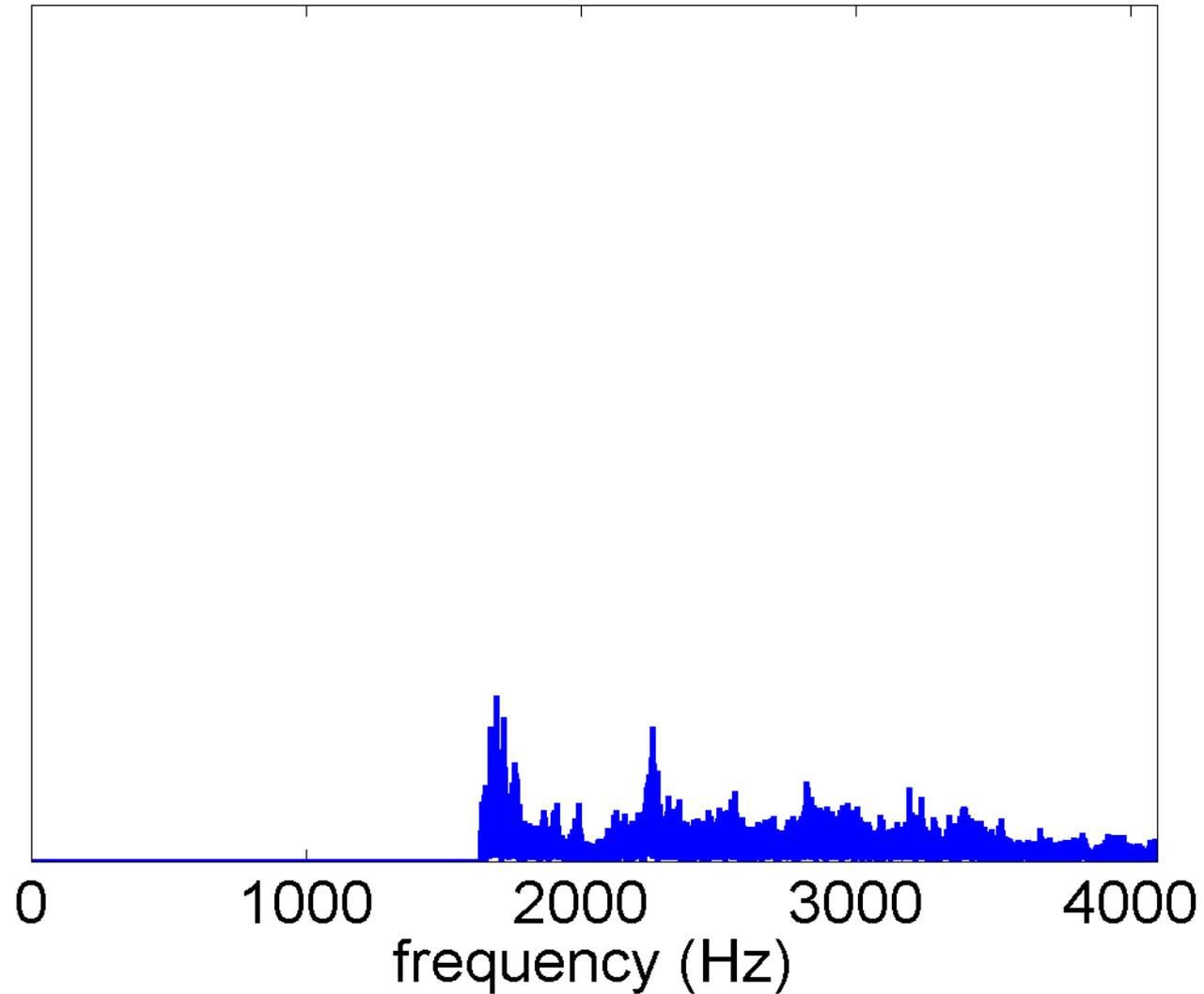
High-pass filter



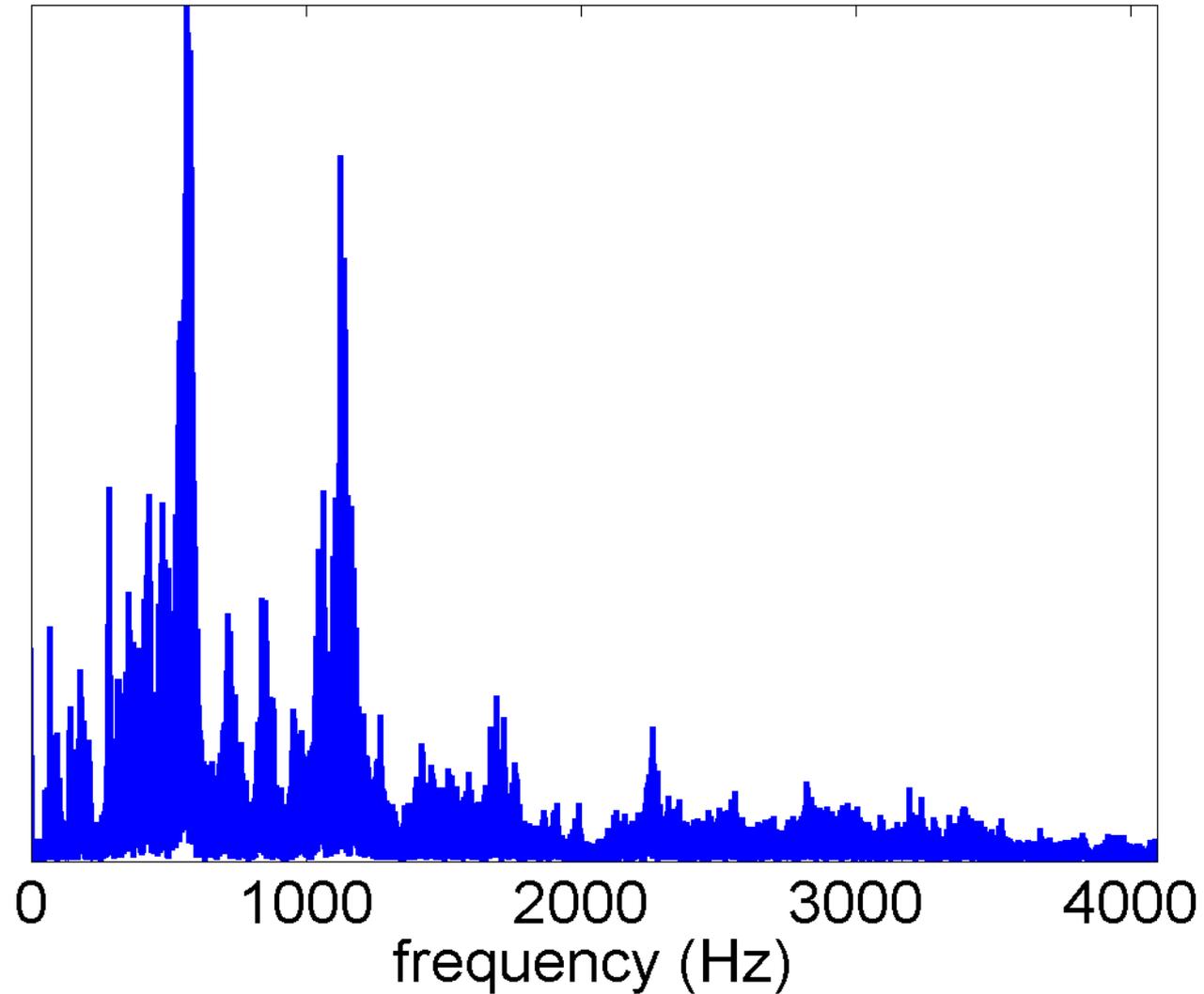
High-pass filter



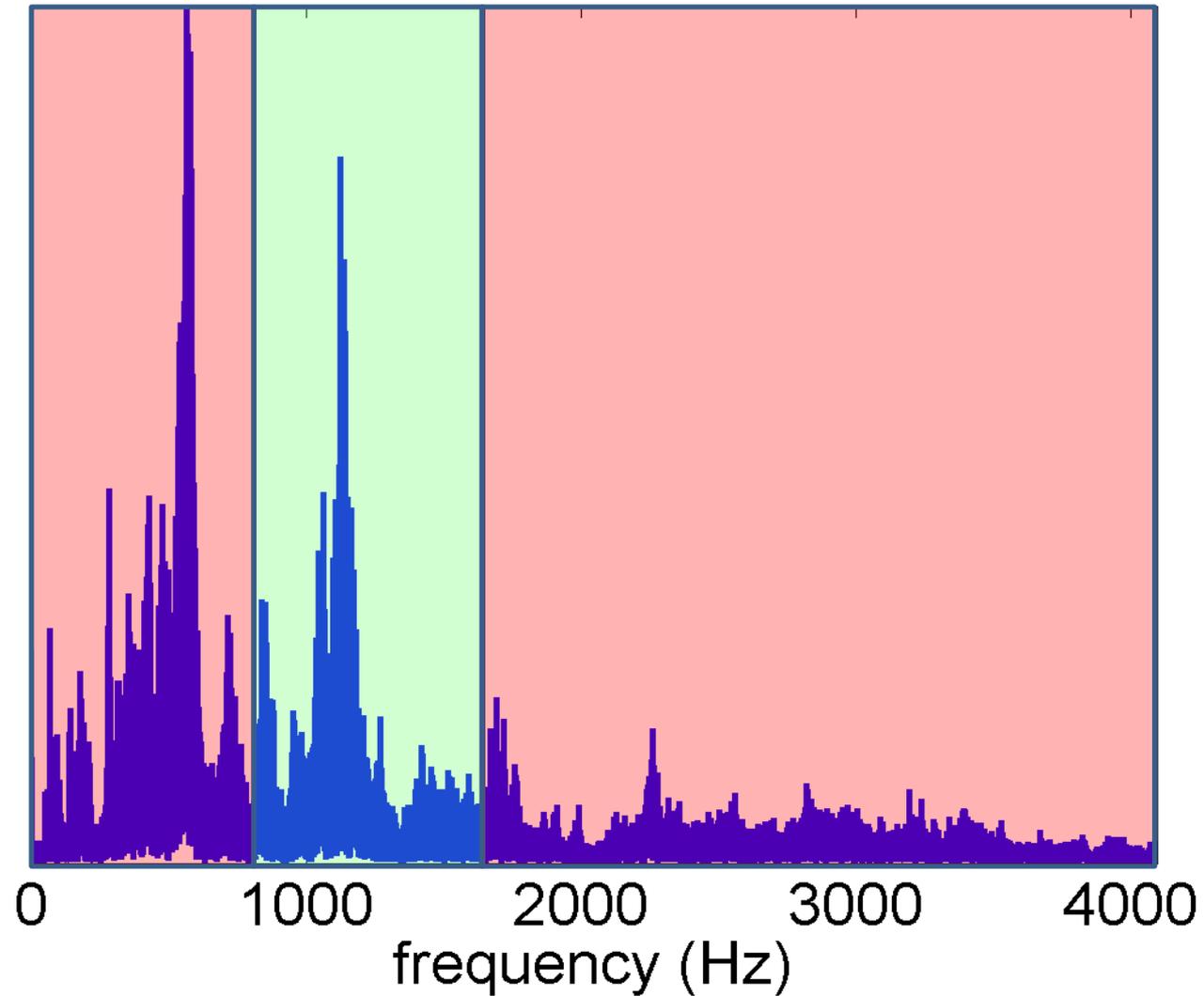
High-pass filter



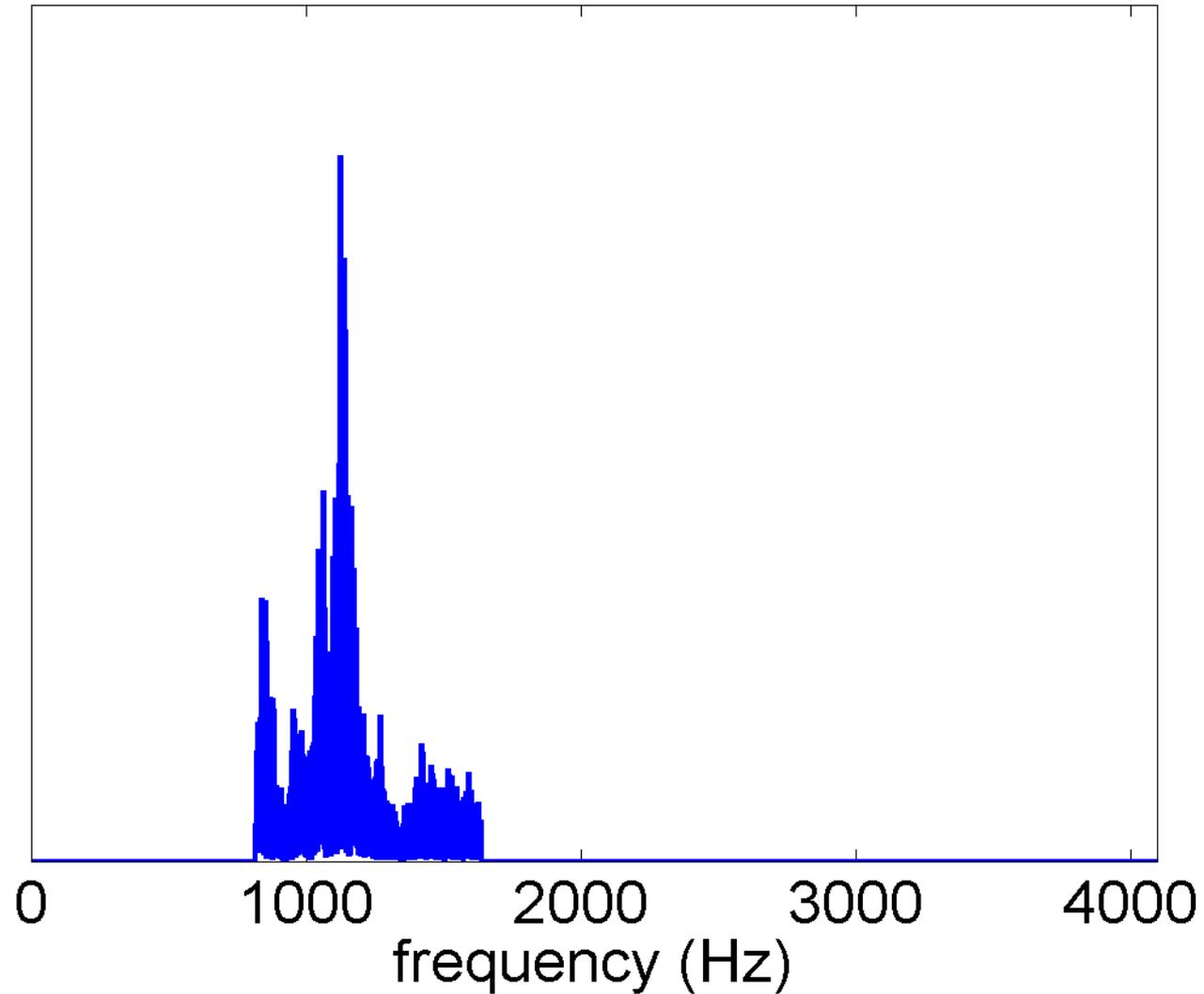
Band-pass filter



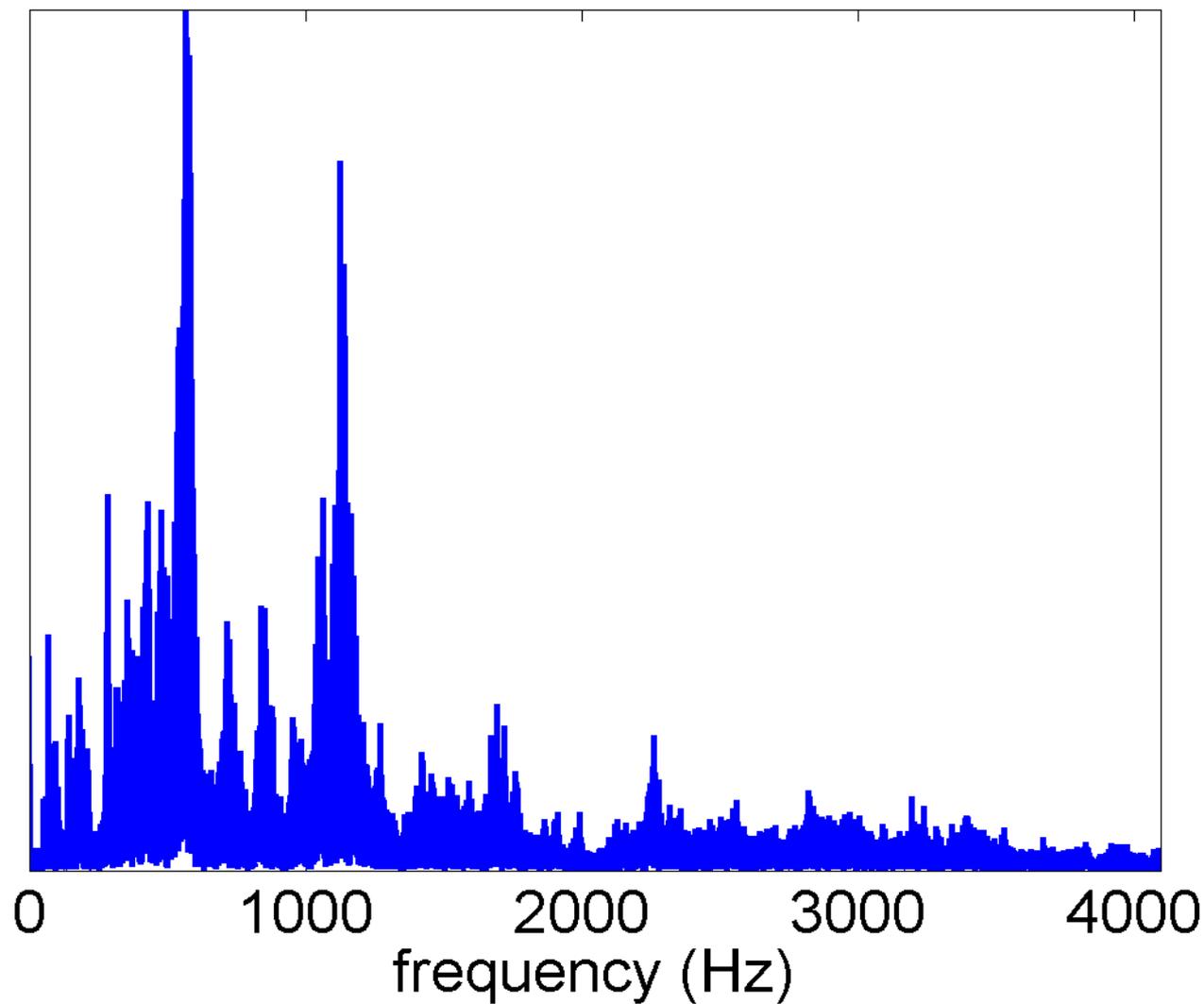
Band-pass filter



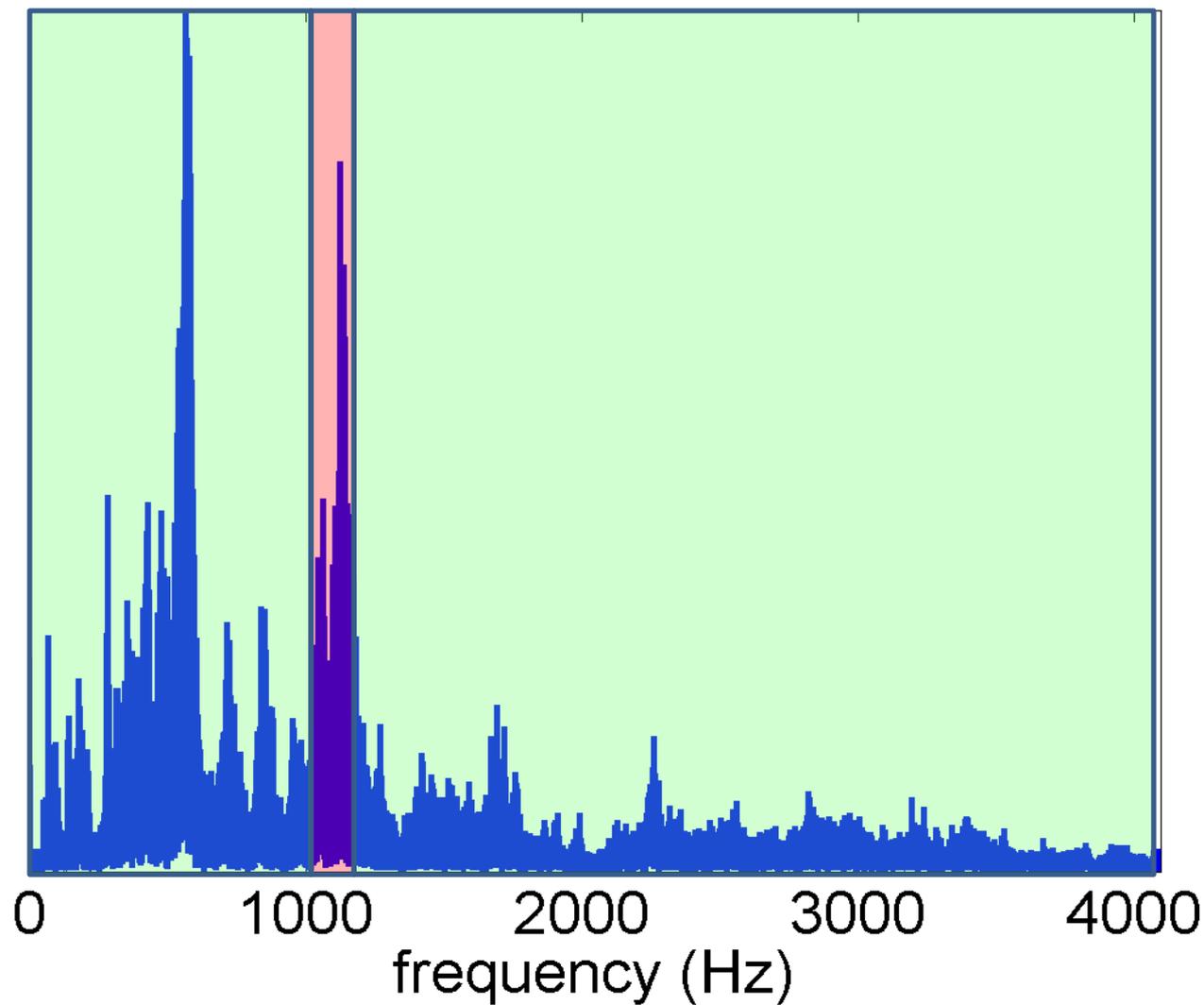
Band-pass filter



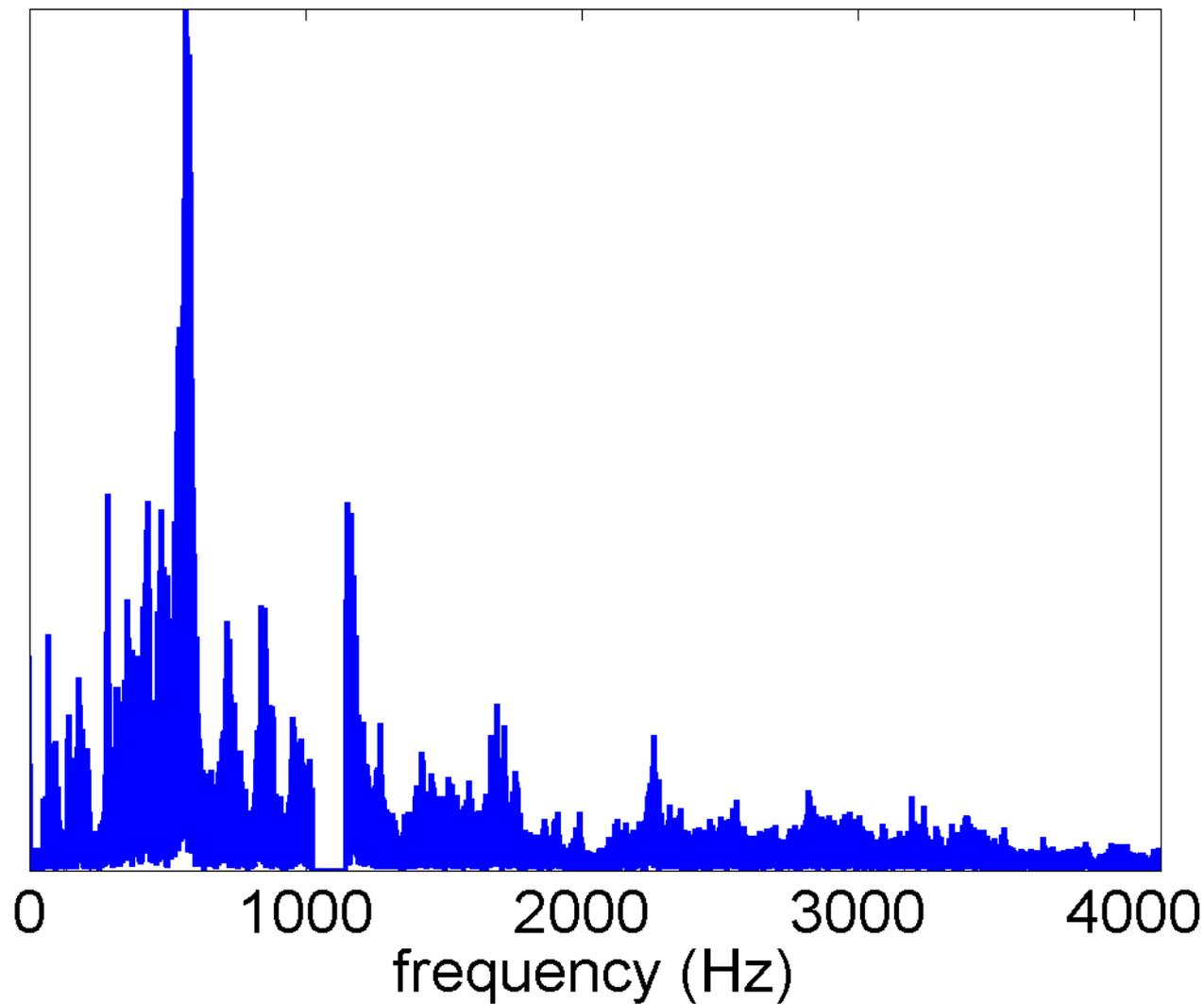
Notch filter



Notch filter



Notch filter





tinyurl.com/filterdemo