San Diego Audio Hackers

Spectrograms Explained

July 10, 2016

Nick Hilton

Outline

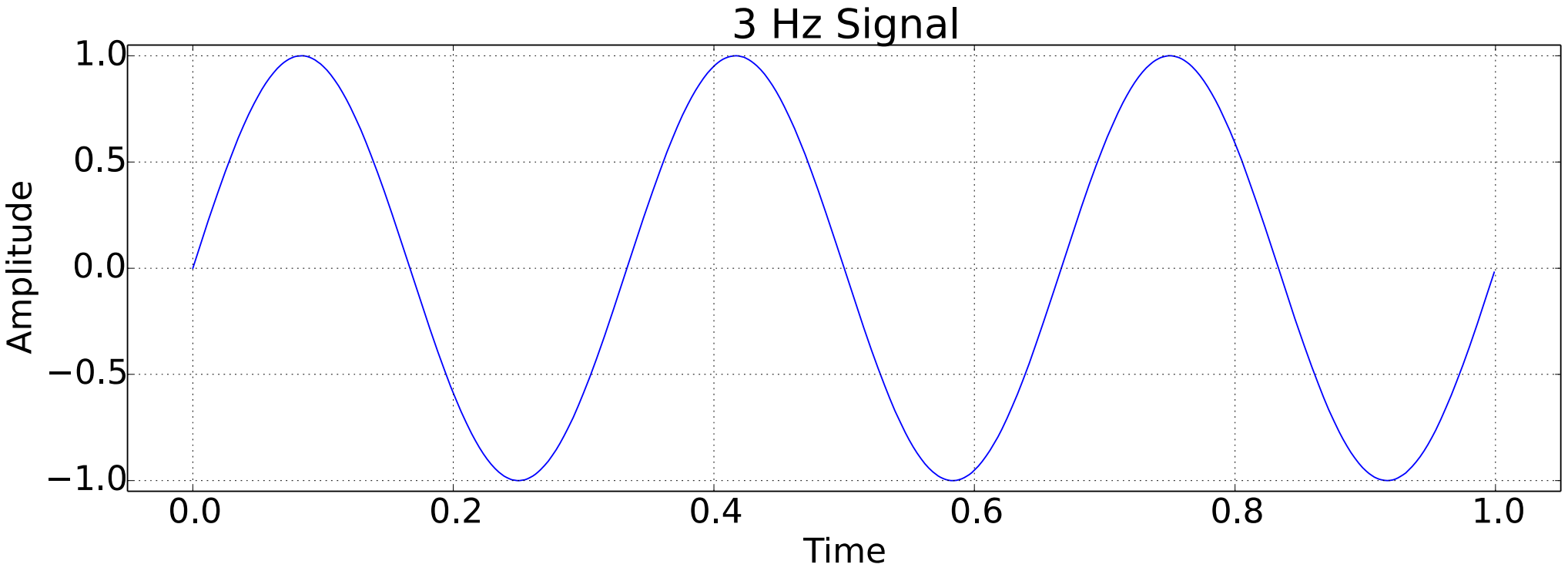
- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

Outline

- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

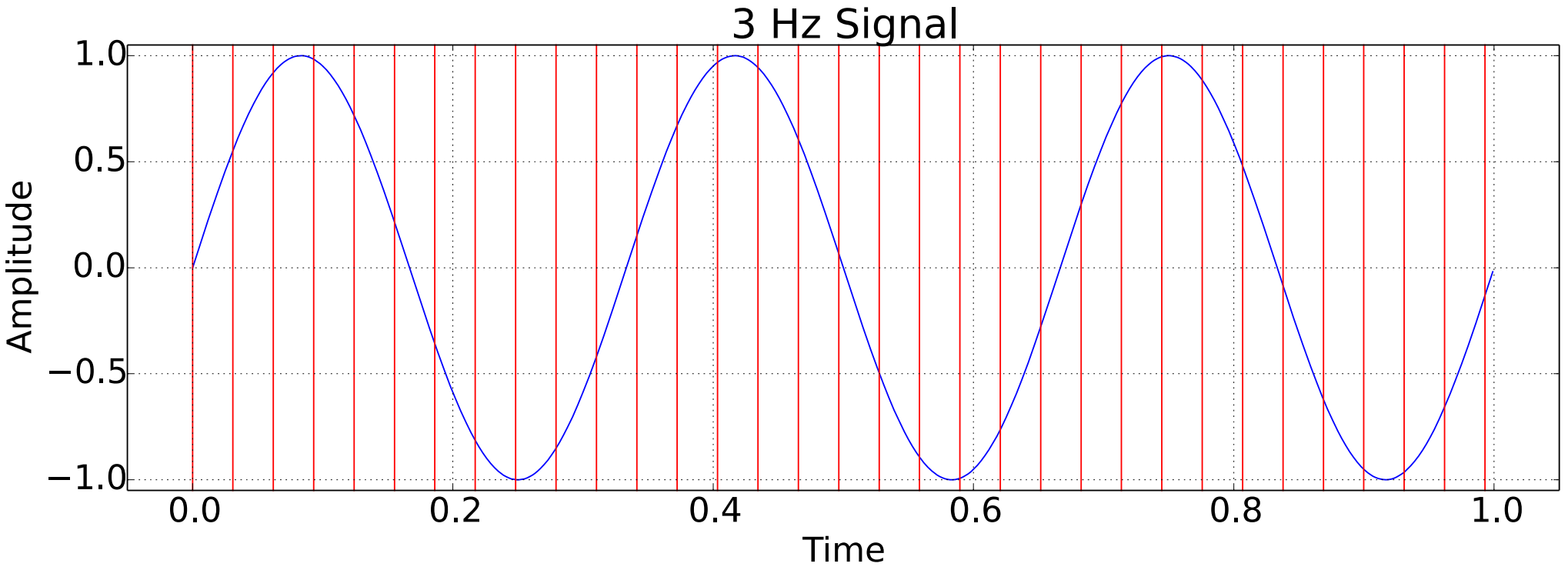
Time domain signals

- List of values
  - {time, amplitude}, {time, amplitude}, ...



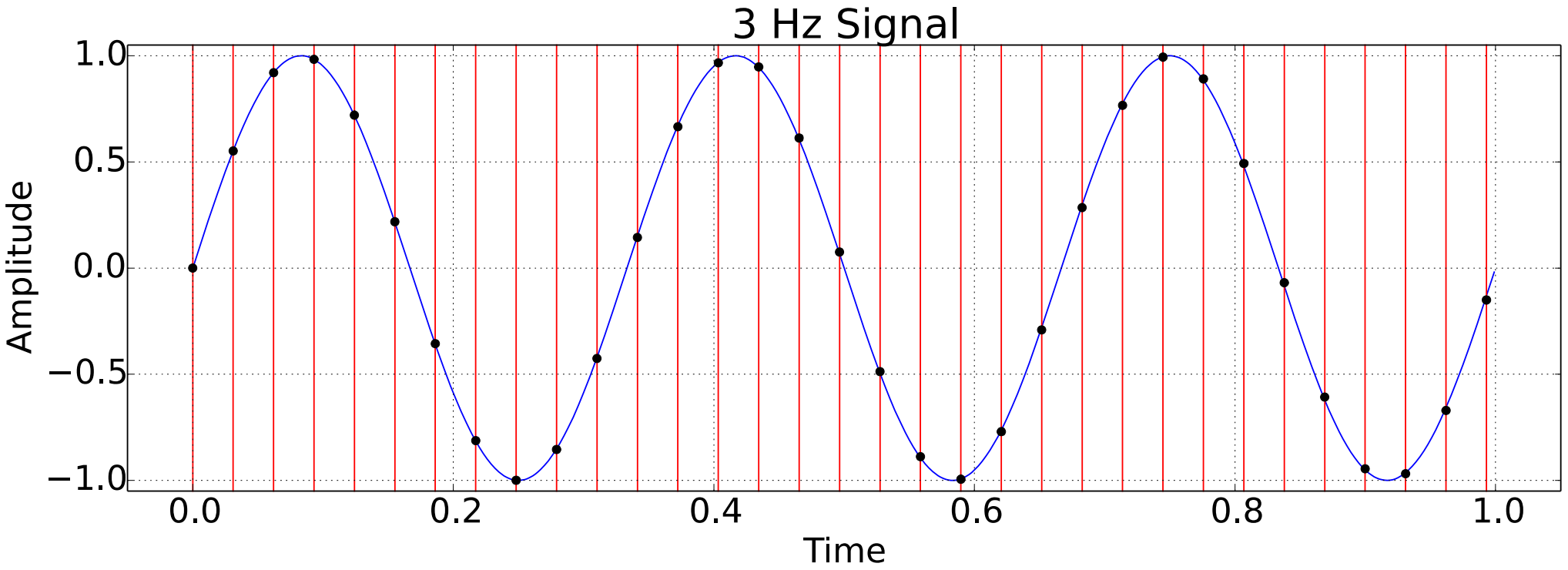
Time domain signals

- List of values
  - {time, amplitude}, {time, amplitude}, ...



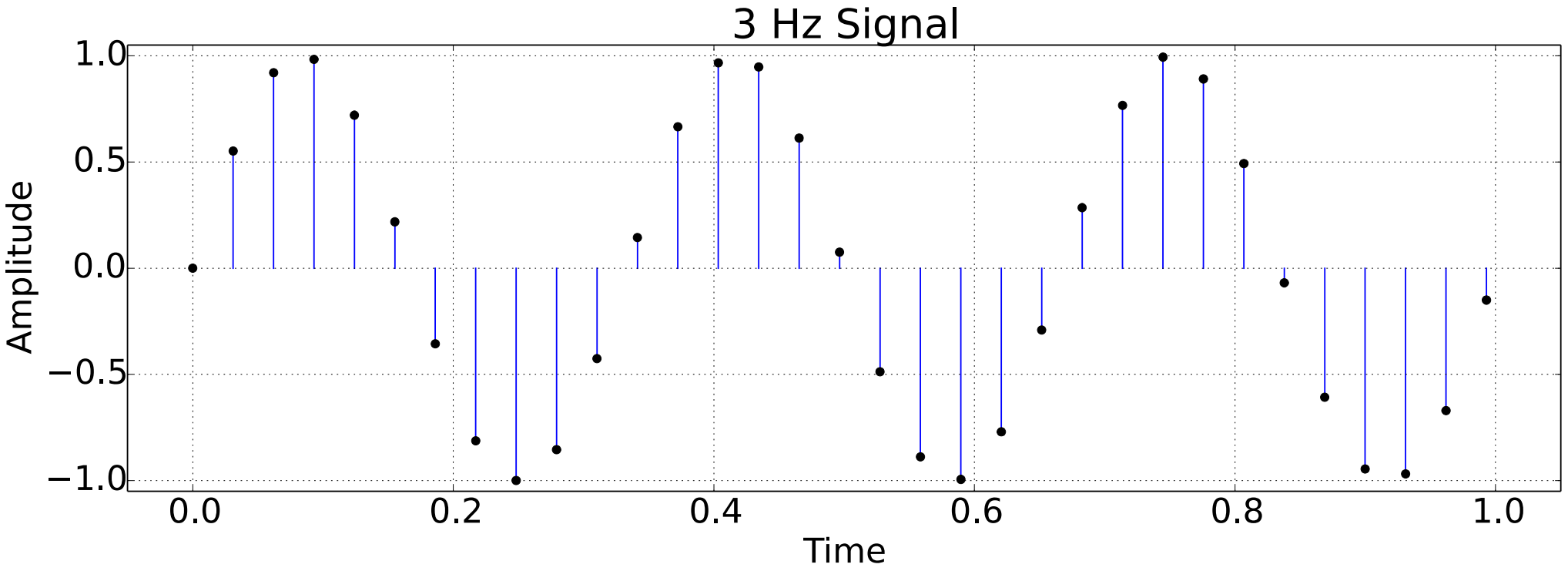
Time domain signals

- List of values
  - {time, amplitude}, {time, amplitude}, ...



Time domain signals

- List of values
  - {time, amplitude}, {time, amplitude}, ...

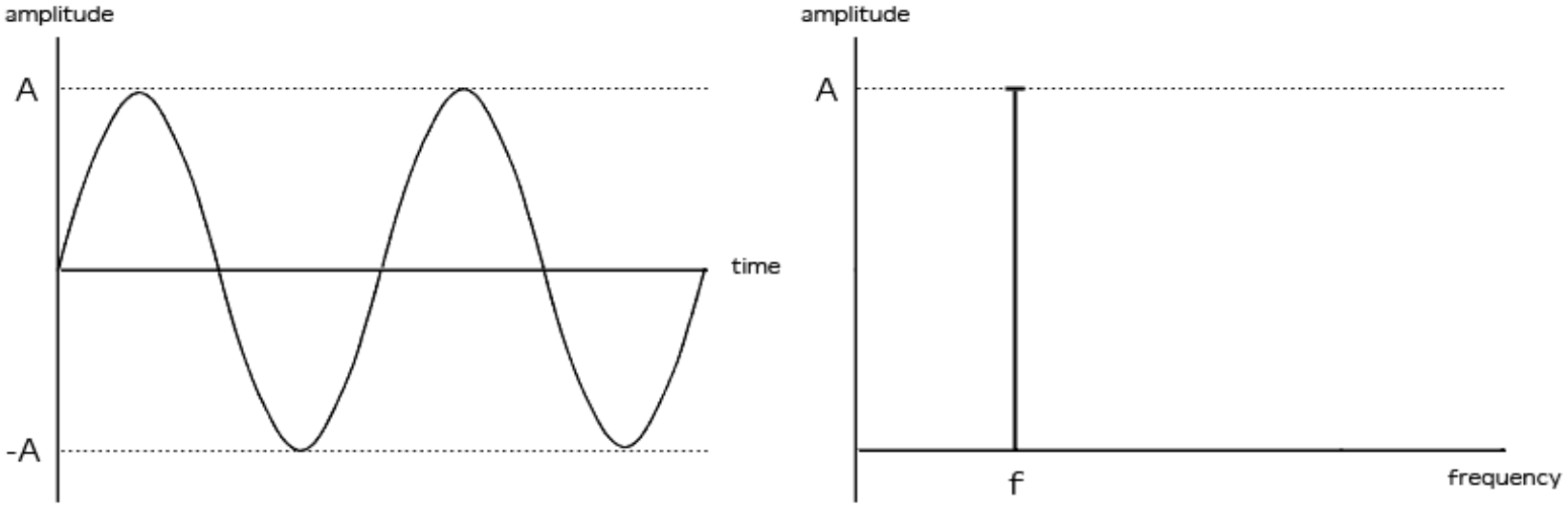


Outline

- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

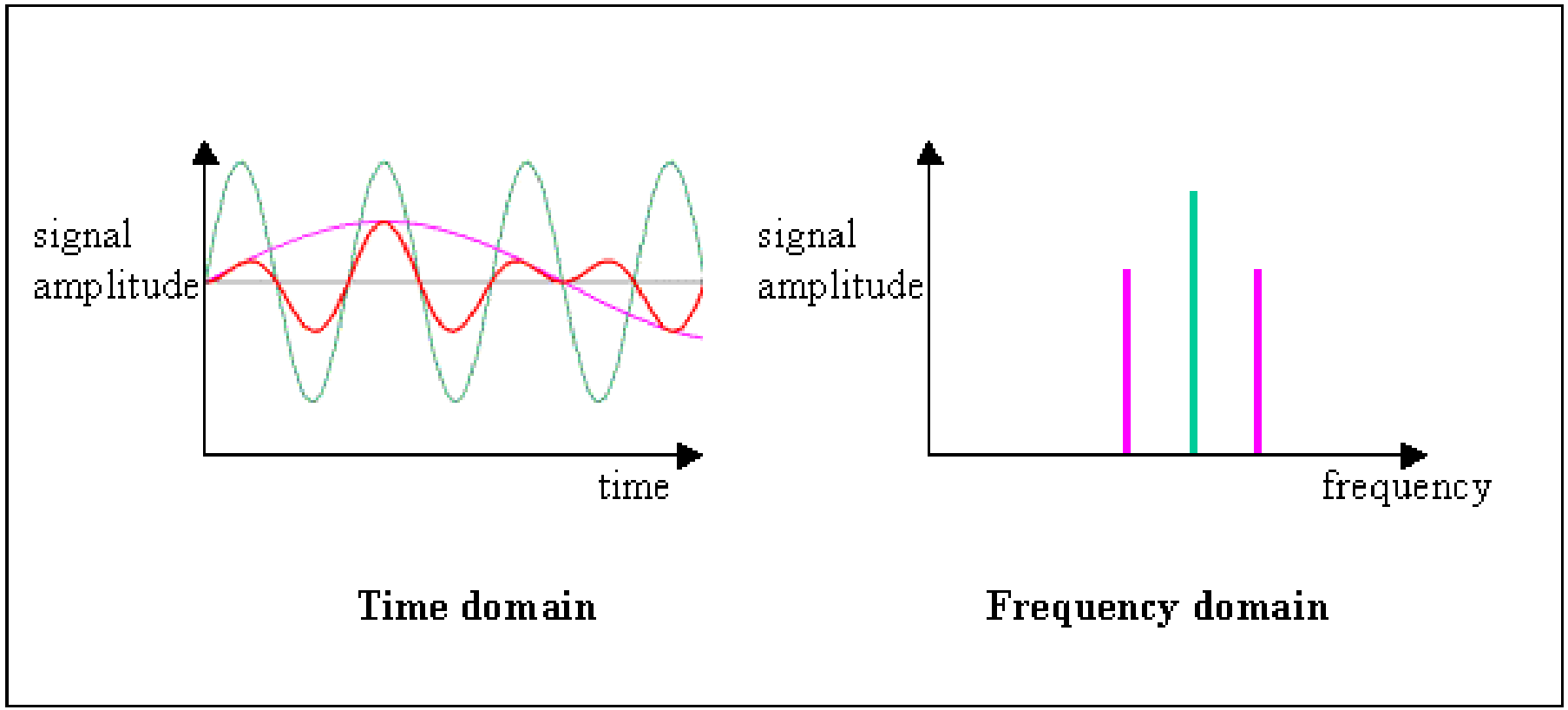
Frequency domain signals

- List of values
  - {frequency, amplitude}, {frequency, amplitude} ...



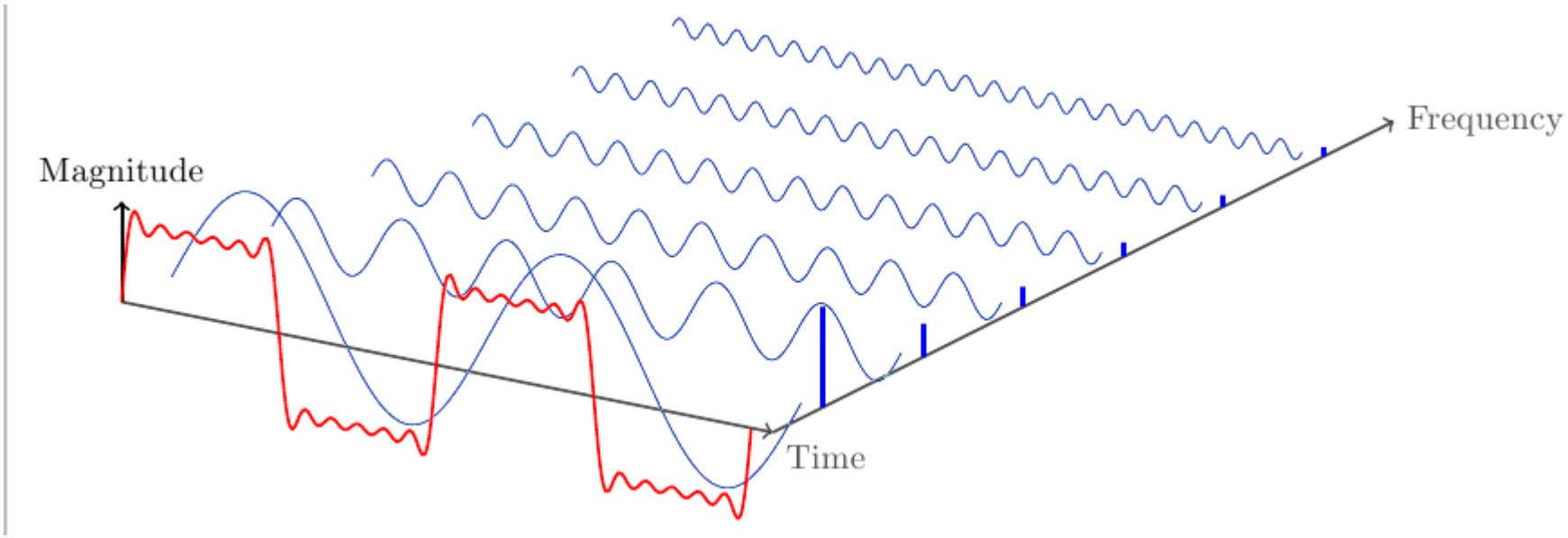
Frequency domain signals

- List of values
  - {frequency, amplitude}, {frequency, amplitude} ...



Frequency domain signals

- List of values
  - {frequency, amplitude}, {frequency, amplitude} ...

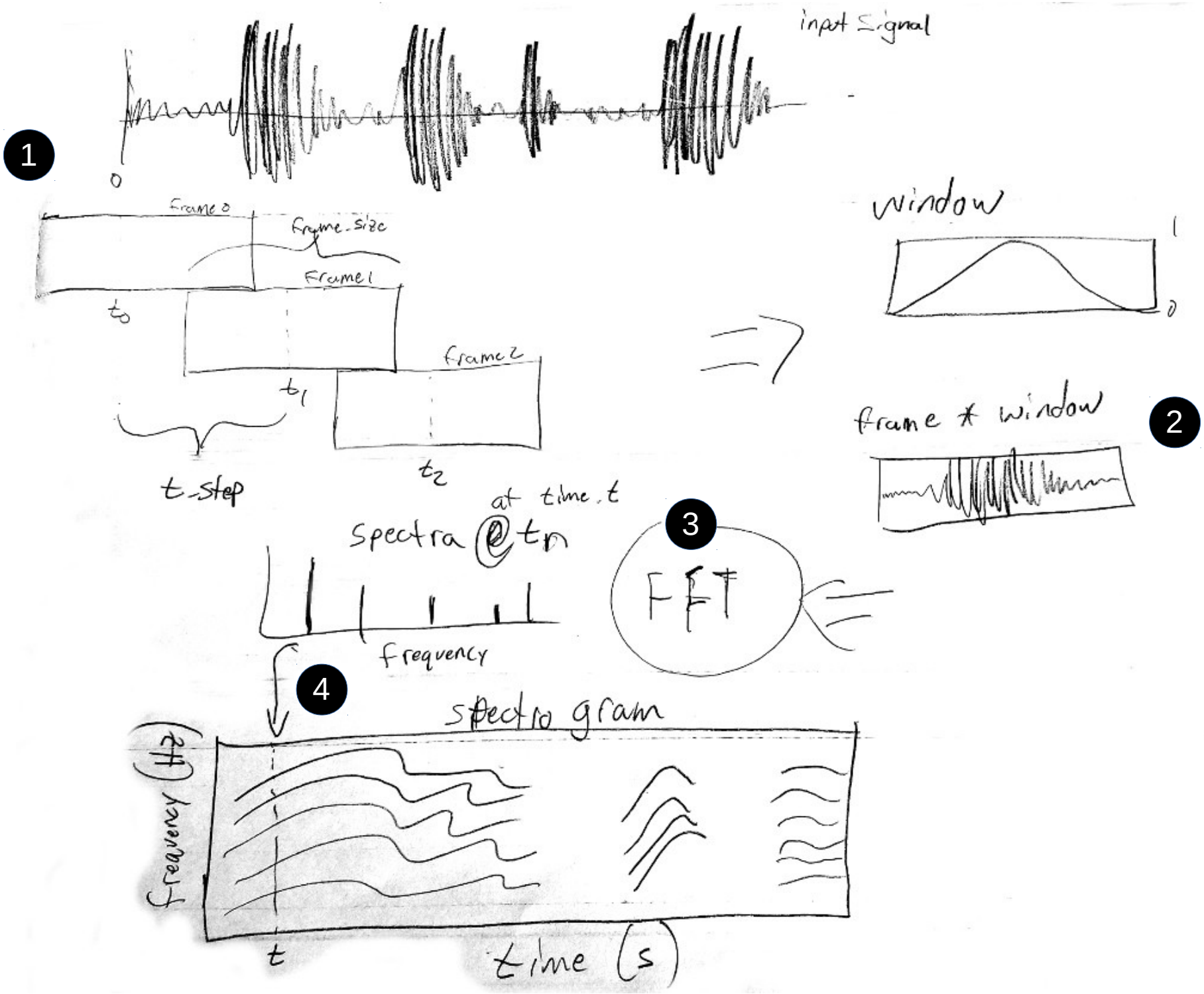


Outline

- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

How to make spectrograms

- Recipe
  1. Break up input signal into frames
  2. Apply a window to remove step function at edge
  3. Transform frame into frequency domain via FFT
  4. Place frequency domain frame into spectrogram matrix


input signal
1
0
Frame 0
Frame_size
Frame 1
t0
Frame 2
t1
t2
t_step
window
1
0
frame * window
2
at time t
Spectra @ tn
3
FFT
frequency
4
spectro gram
frequency (Hz)
t
time (s)

Outline

- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

The Heisenberg uncertainty principle

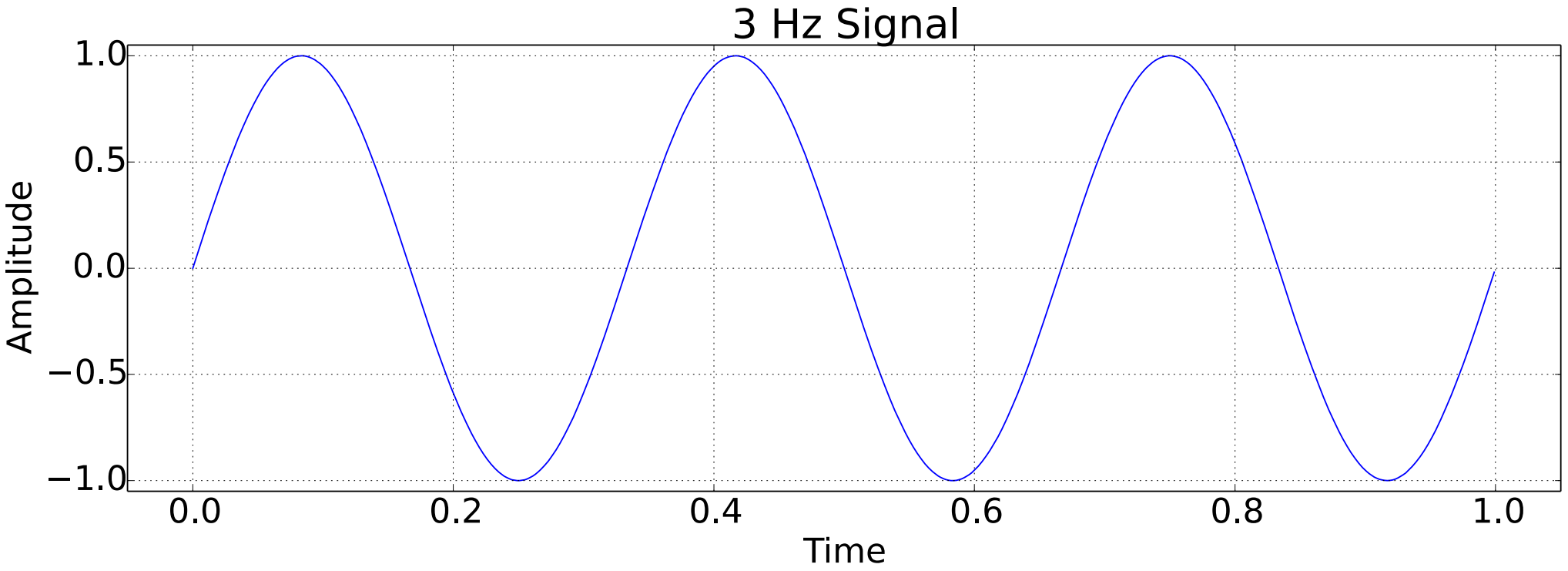
- Formula

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

- Meaning for signal processing
  - You can't know frequency & time precisely simultaneously

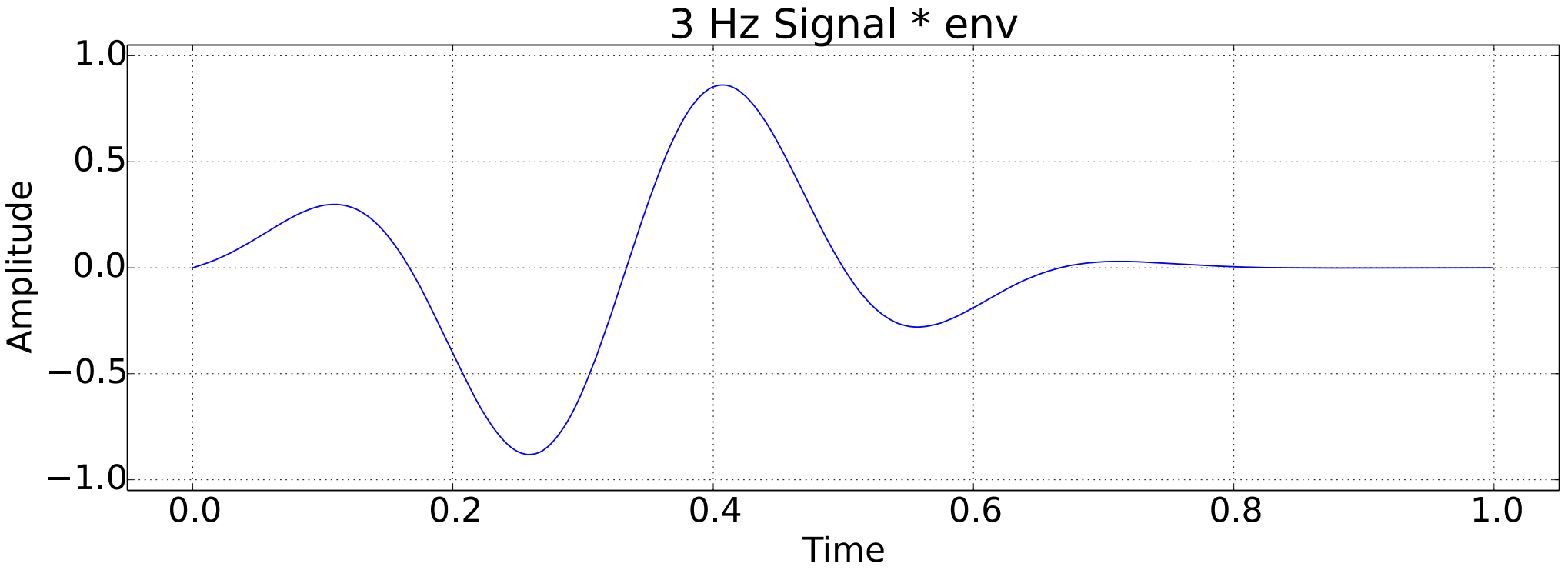
The Heisenberg uncertainty principle

- When is the signal 3 Hz?



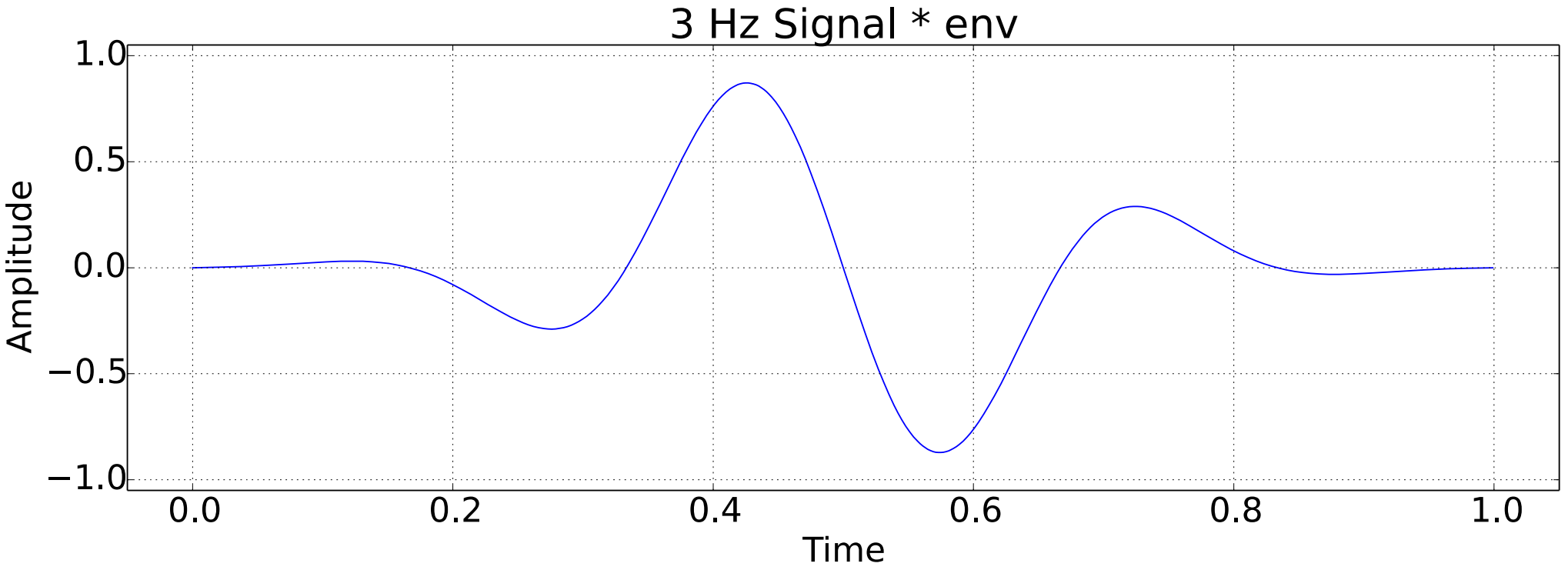
The Heisenberg uncertainty principle

- When is the signal 3 Hz?



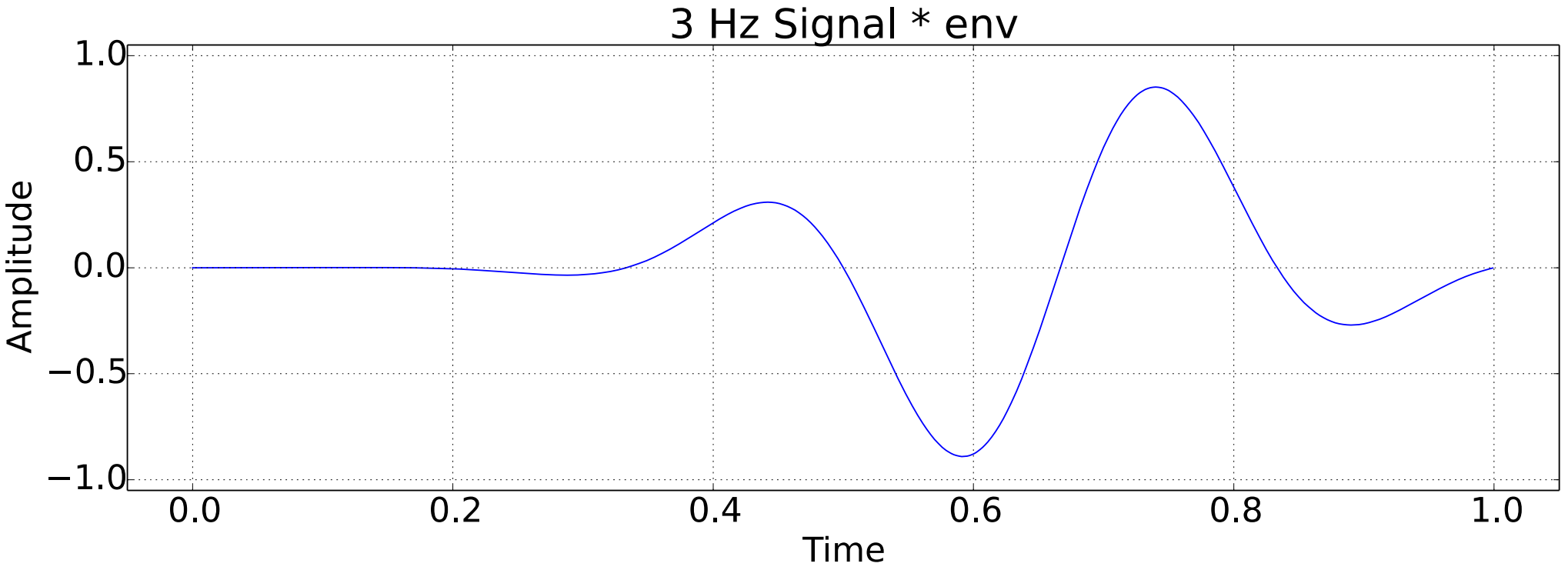
The Heisenberg uncertainty principle

- When is the signal 3 Hz?



The Heisenberg uncertainty principle

- When is the signal 3 Hz?

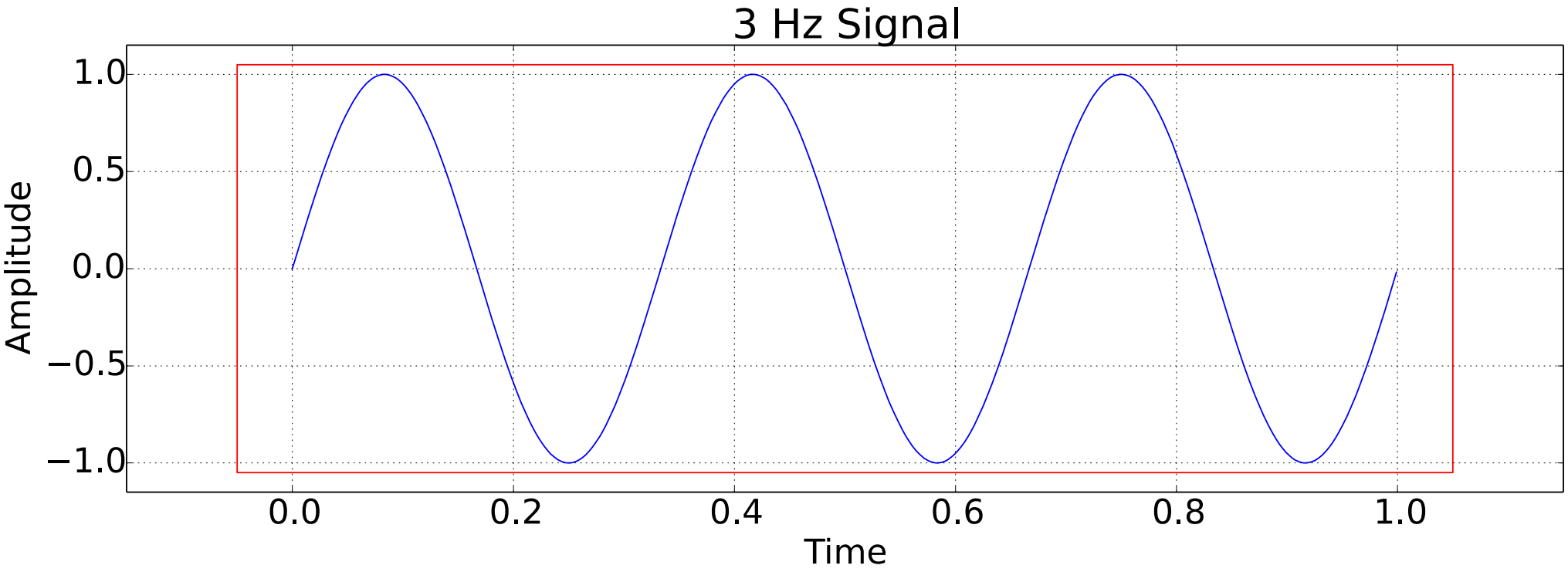


The Heisenberg uncertainty principle

- We must process a finite duration of the signal
  - So we reduce the amount memory used
  - But more importantly, so we can know approximately *when* the signal contains which frequencies

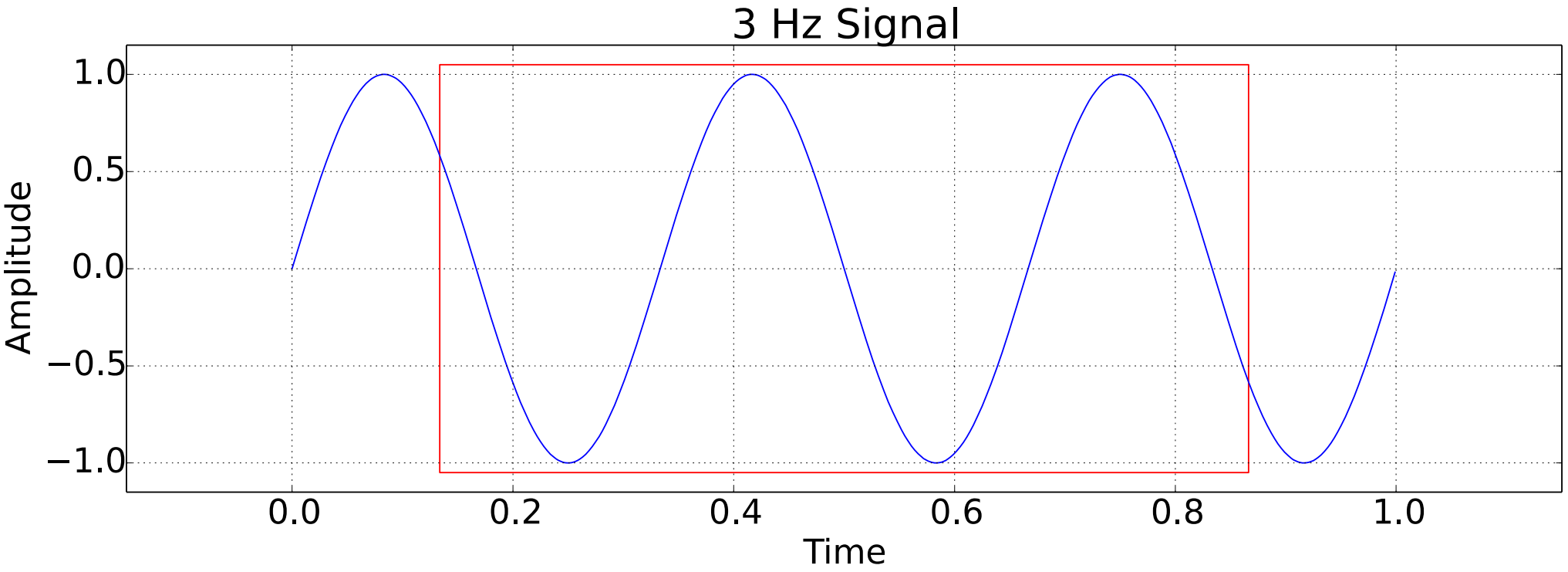
The Heisenberg uncertainty principle

- Choosing a finite “window”
  1. Limits the minimal observable frequency



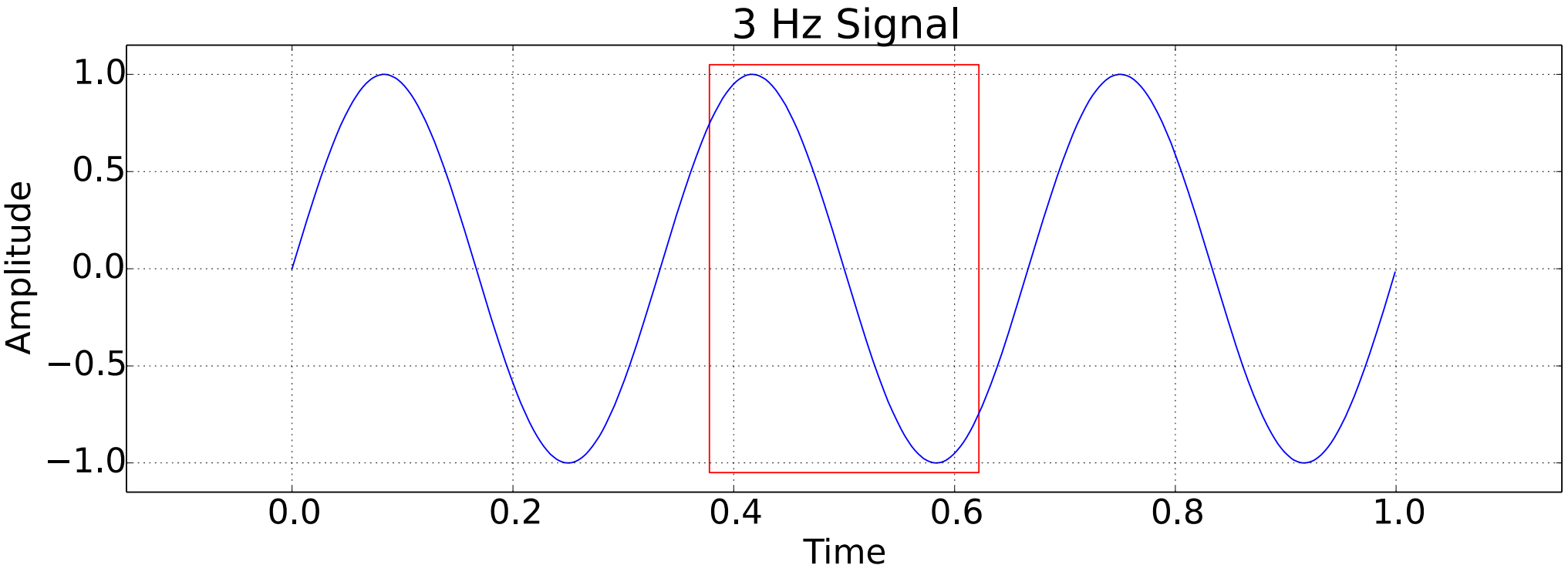
The Heisenberg uncertainty principle

- Choosing a finite “window”
  1. Limits the minimal observable frequency



The Heisenberg uncertainty principle

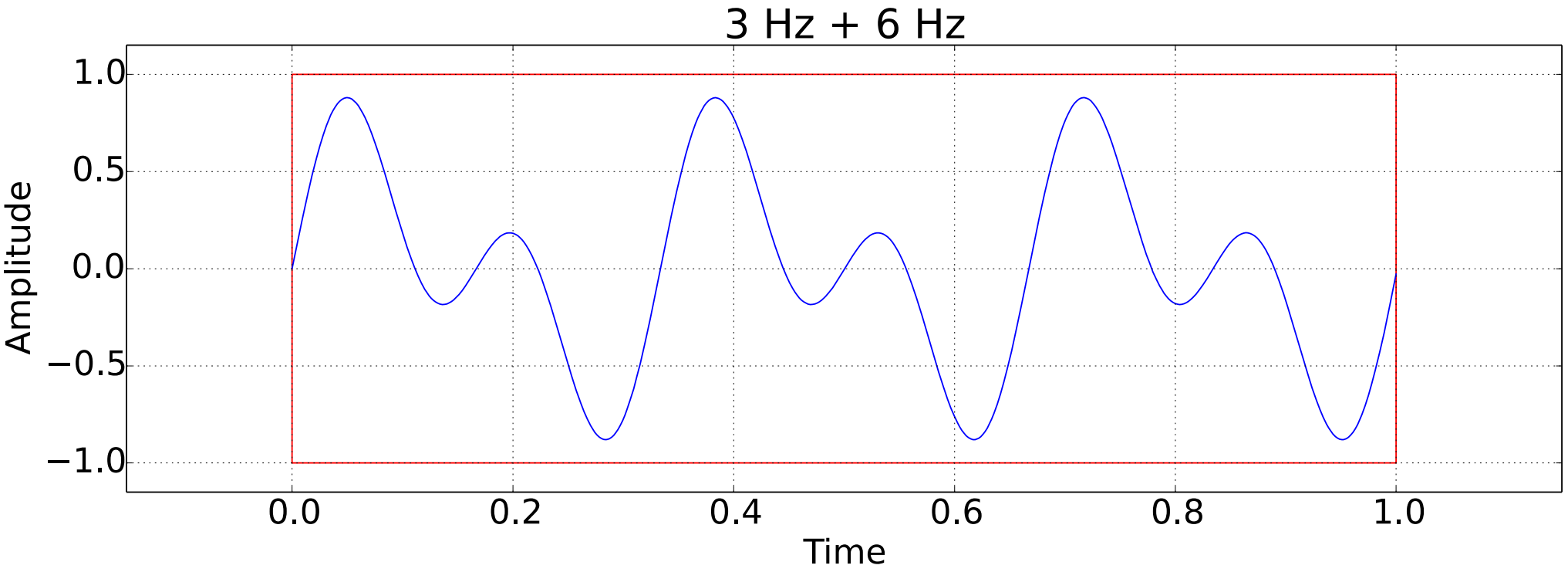
- Choosing a finite “window”
  1. Limits the minimal observable frequency



The Heisenberg uncertainty principle

- Choosing a finite “window”

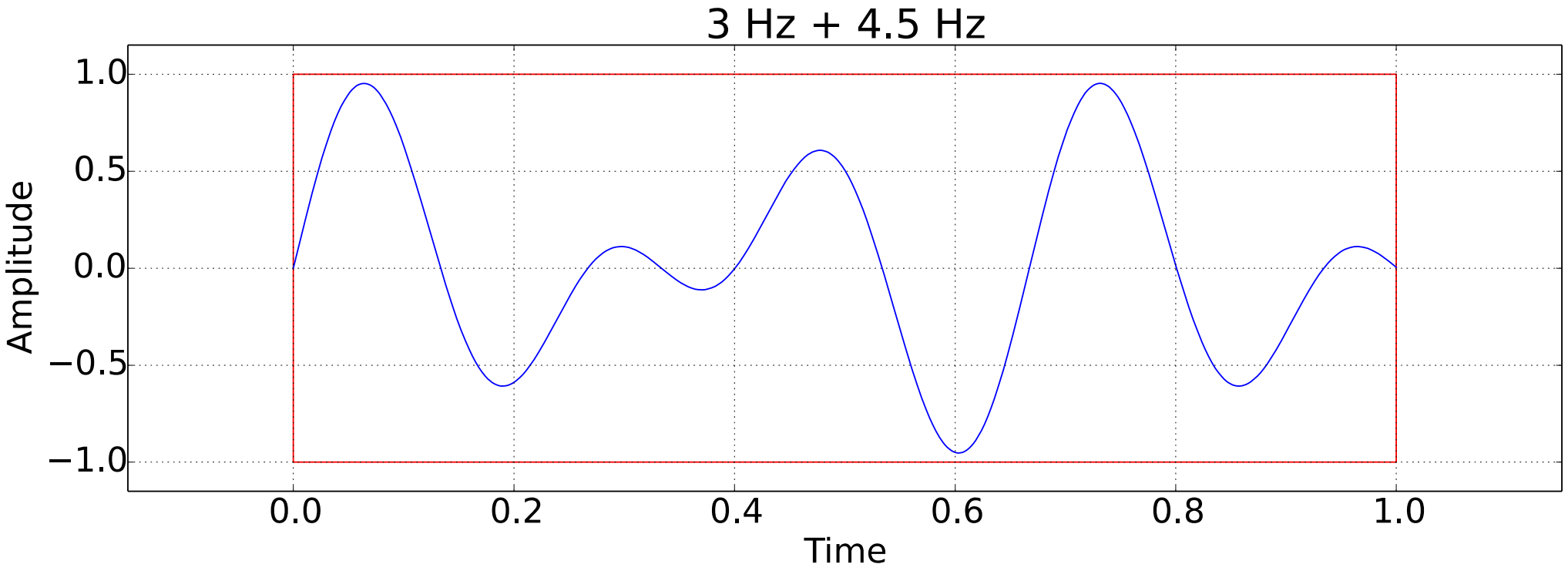
2. Limits if two tones can be resolved



The Heisenberg uncertainty principle

- Choosing a finite “window”

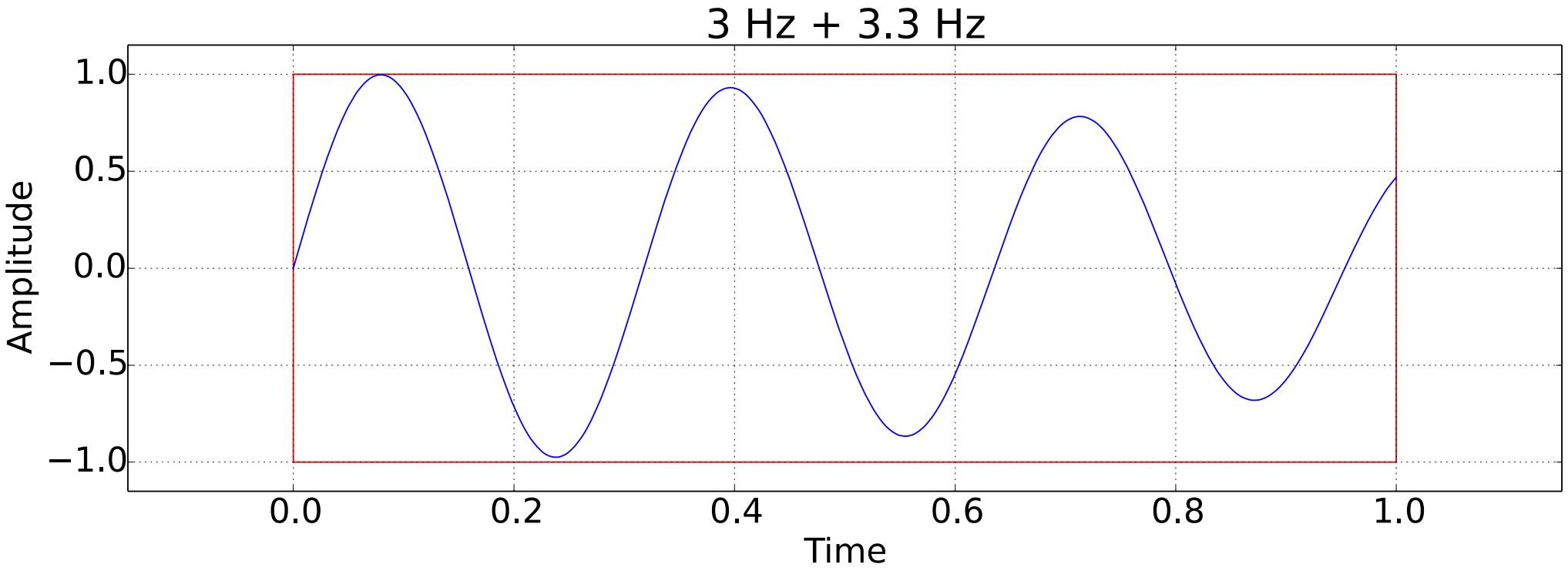
2. Limits if two tones can be resolved



The Heisenberg uncertainty principle

- Choosing a finite “window”

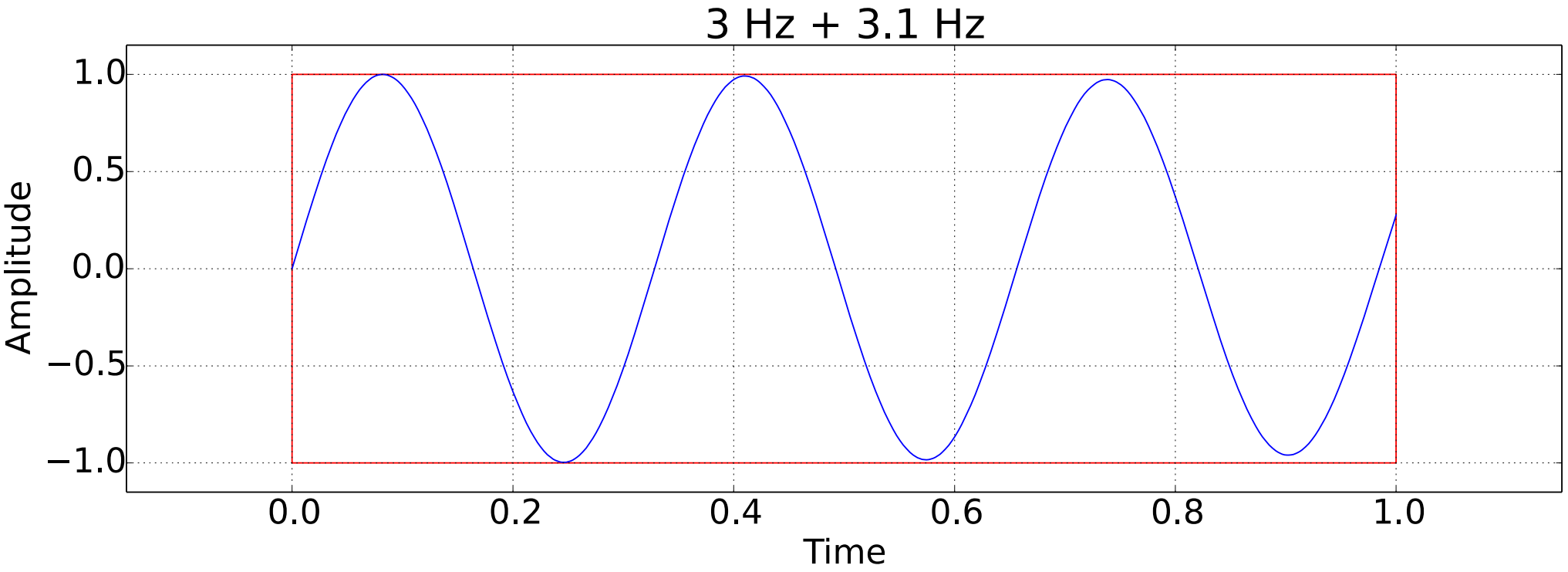
2. Limits if two tones can be resolved



The Heisenberg uncertainty principle

- Choosing a finite “window”

2. Limits if two tones can be resolved



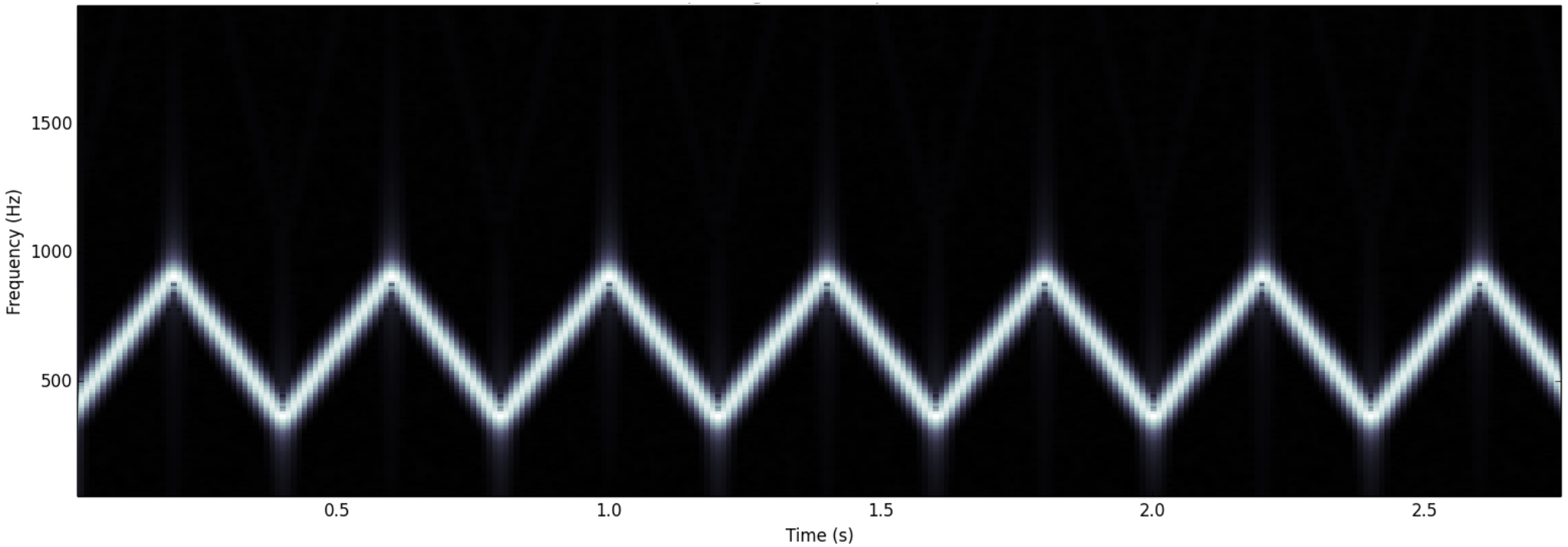
The Heisenberg uncertainty principle

- A trade off must be made
  - Time resolution
  - Frequency resolution
  - You can't have both!

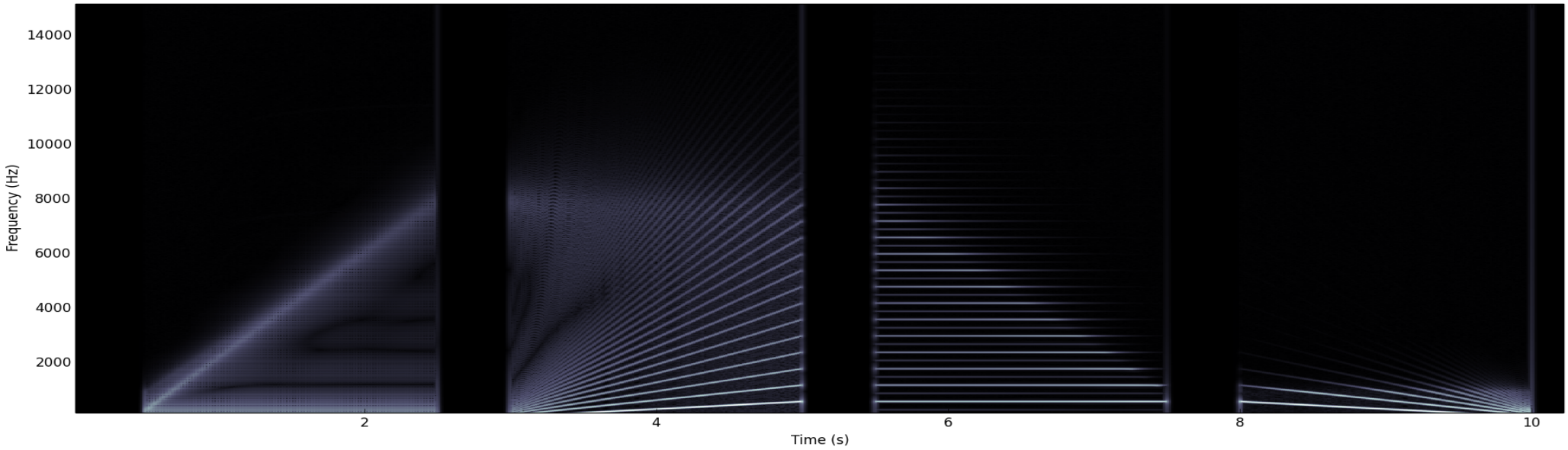
Outline

- Time domain signals
- Frequency domain
- How to make spectrograms
- Heisenberg uncertainty principle
- Spectrograms

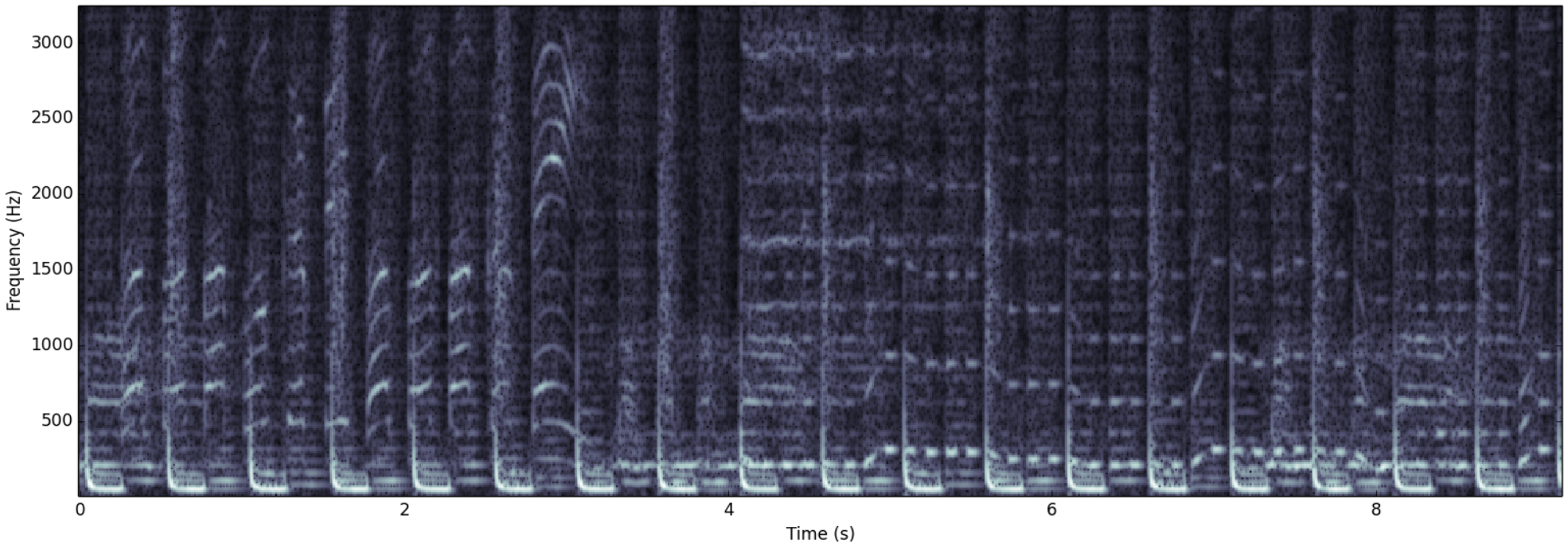
Spectrograms



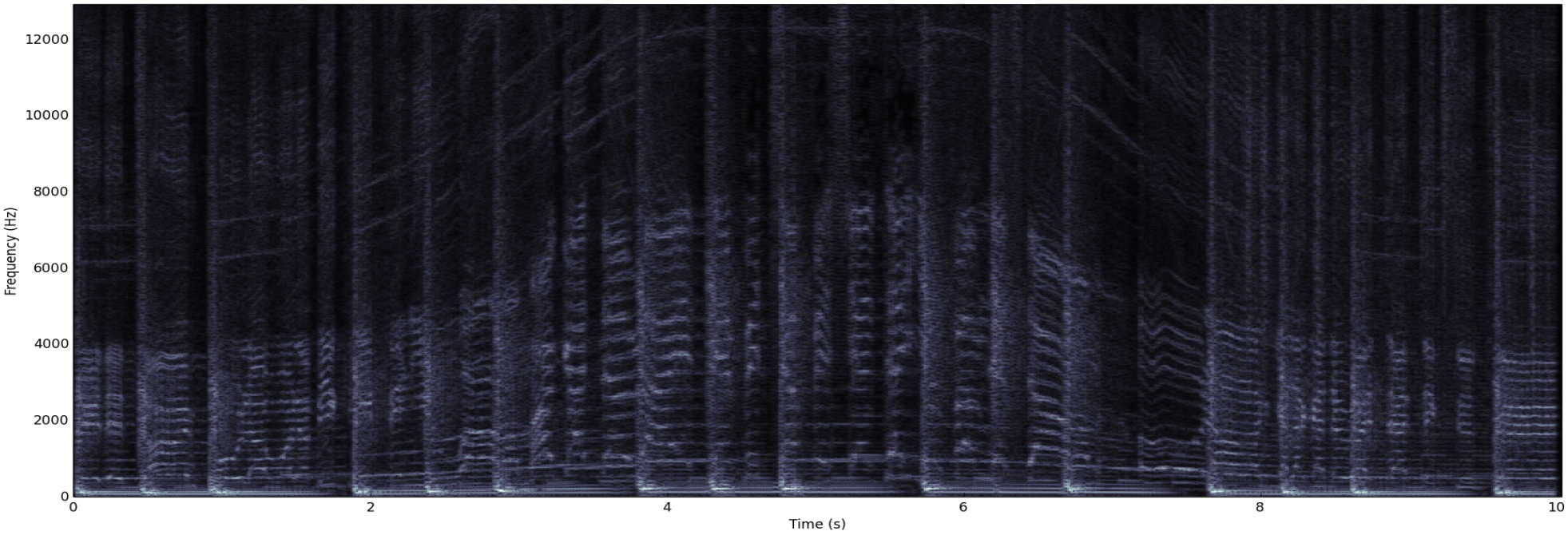
Spectrograms



Spectrograms



Spectrograms



Spectrograms