ECS614U/ECS749P: Sound Recording and Production

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Semester 1, 2013–14

Course Overview

Lectures

1. The Physics of Sound.
2. Microphones.
3. The Audio Chain.
4. MIDI.
5. Sound Design.
6. Mixing: Gain.
7. Mixing: Delay.
8. Mixing: Dynamics.
9. Sound Reproduction.
10. Psychoacoustics.
11. Mastering.

Coursework

1. Microphone project: **5%** (11/10/2013).
2. Apple loops project: **10%** (25/10/2013).
3. Soundscape concept document: **30%** (22/11/2013).
4. Soundscape audio and technical document: **55%** (13/12/2013).

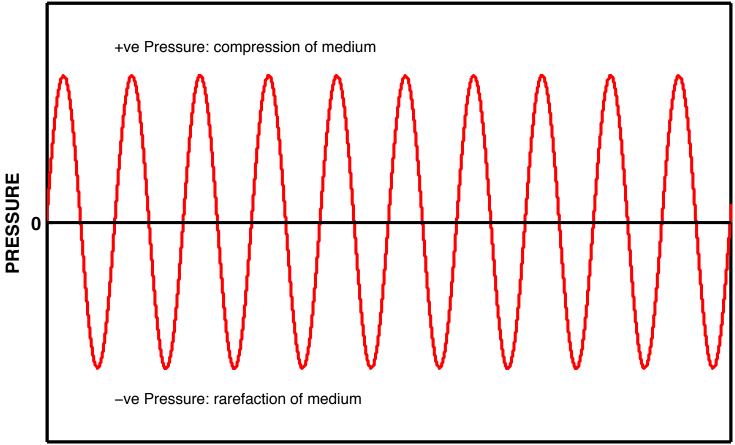
The Physics of Sound

What is a sound?

- A sound is a pressure wave.
- The pressure wave travels through an acoustic medium, i.e. air.
- The pressure wave consisting of compression and rarefaction.
- In the compression and rarefaction parts of the wave, the particles which form the acoustic medium are respectively squashed together and pulled apart.
- *Vibrating string animation*.

The waveform

- A waveform is a graphical representation of a sound wave.



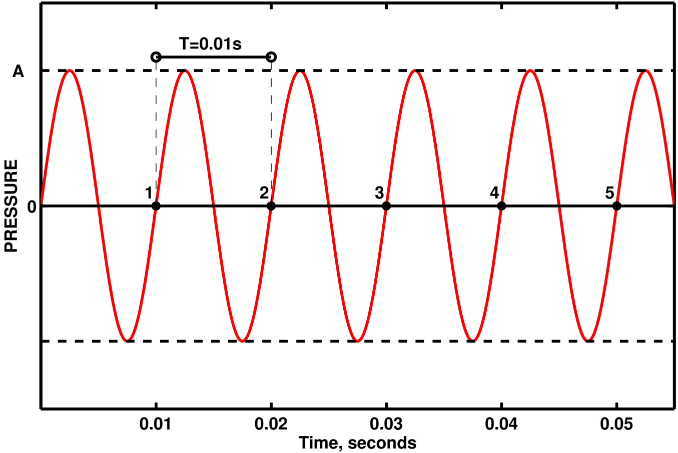
The waveform

- A waveform plot can represent one of two things:
  1. The waveform at a given point in space as it changes with time.
  2. The waveform at a given moment in time as it changes in space.
- *Waves in space and time*.
- When listening to a sound we are sensing the changes in pressure with time.

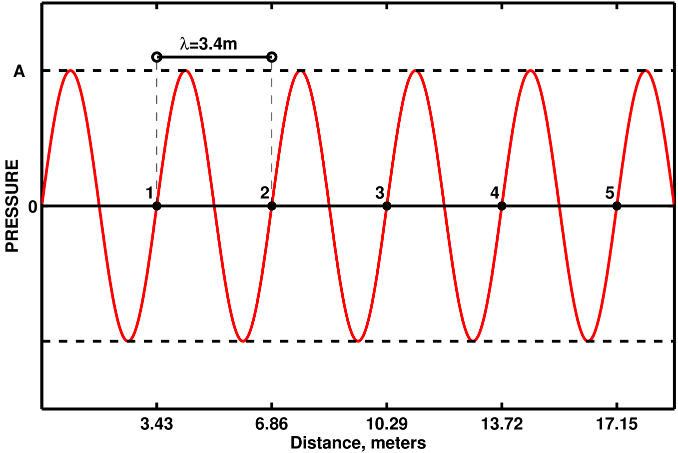
Sound wave properties

- Amplitude, **A** (Pa).
- Frequency, **f** (Hz): number of cycles per second.
- Time period, **T** (s): the time for one cycle.
- Wavelength, λ (m): the distance taken up by one cycle.
- Speed **c** (m/s): the speed at which the wave travels.

A waveform versus time



A waveform versus distance



The relationship between time and space

$$\textbf{TIME} = \frac{\textbf{1}}{\textbf{FREQUENCY}} \quad \Longrightarrow \quad \textbf{T} = \frac{\textbf{1}}{\textbf{f}}$$

$$\textbf{WAVELENGTH} \times \textbf{FREQUENCY} = \textbf{SPEED} \quad \Longrightarrow \quad \lambda \times \textbf{f} = \textbf{c}$$

$$\textbf{DISTANCE} = \textbf{SPEED} \times \textbf{TIME} \quad \Longrightarrow \quad \textbf{d} = \textbf{c} \times \textbf{t}$$

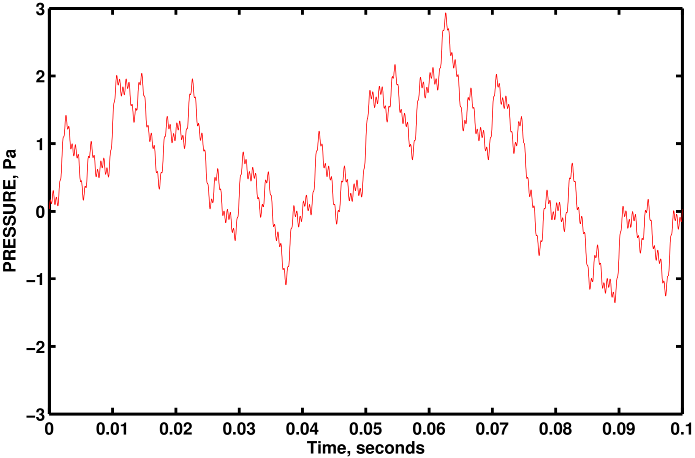
(The speed of sound in air (**c**) is 343 m/s)

Complex waveforms

- Real musical sounds are more complex than the sine waves shown so far.
- But...we can think of a complex waveform as a summation of many different sine waves of different amplitude, frequency (and phase).

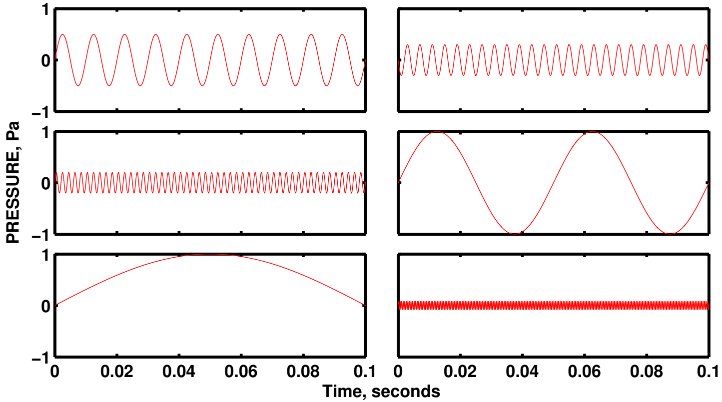
Complex waveforms

This complex waveform...



Complex waveforms

...is made by summing these six simple waveforems.

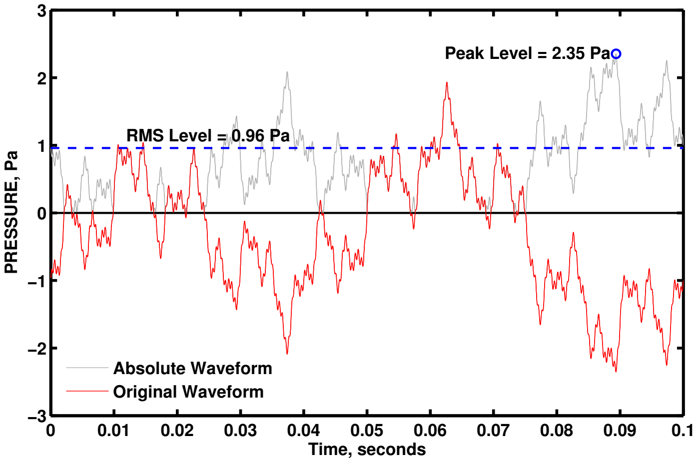


Sound Features

- There are many different features that we can use to describe a sound.
- Today we will consider two types of sound feature:
  - Level features.
  - Spectral features.

Level Features

There are two key level features: **RMS** and **Peak** level.

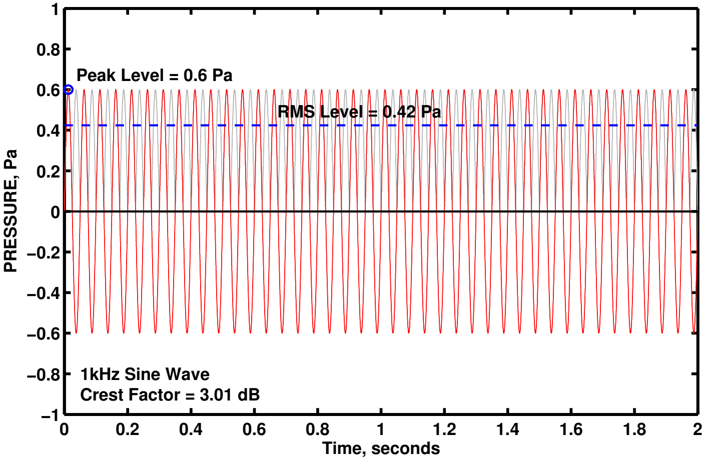


Level Features: dynamics

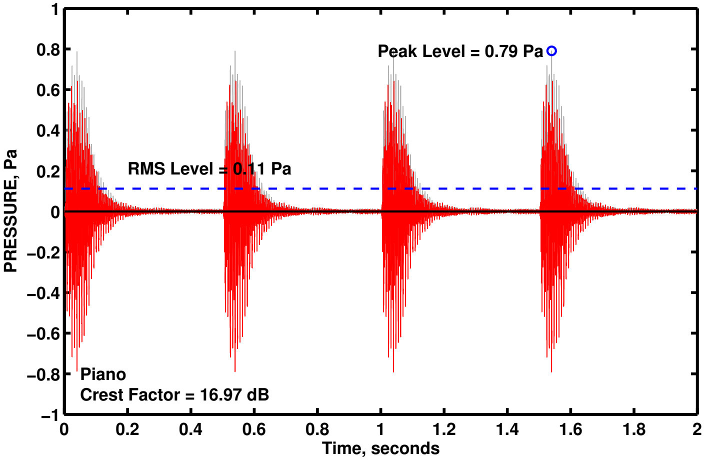
- The term **dynamics** is used to describe how much a sound varies over time.
  - **Transient sounds** - large fluctuations in amplitude, e.g. percussion.
  - **Steady-state sounds** - minimal fluctuations in amplitude, e.g. constant sine-wave.
- The **dynamics** are quantified using the **Crest Factor**, which is the logarithmic ratio of **Peak** and **RMS** levels:

$$\textbf{Crest\ \ Factor} = 20\log_{10}\left(\frac{\textbf{Peak}}{\textbf{RMS}}\right) \tag{1}$$

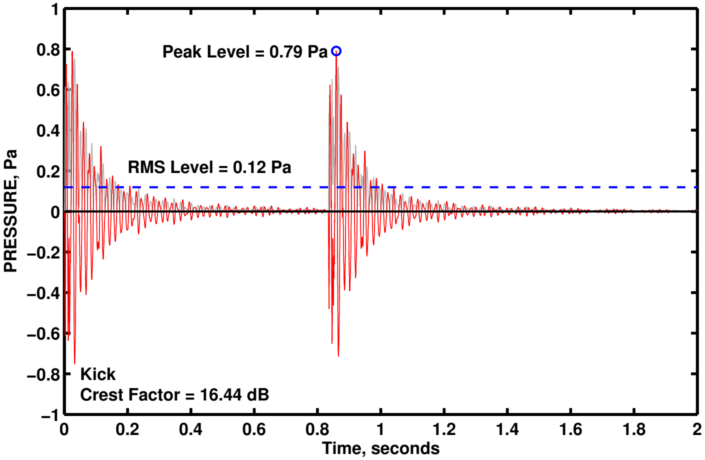
Level Features: dynamics



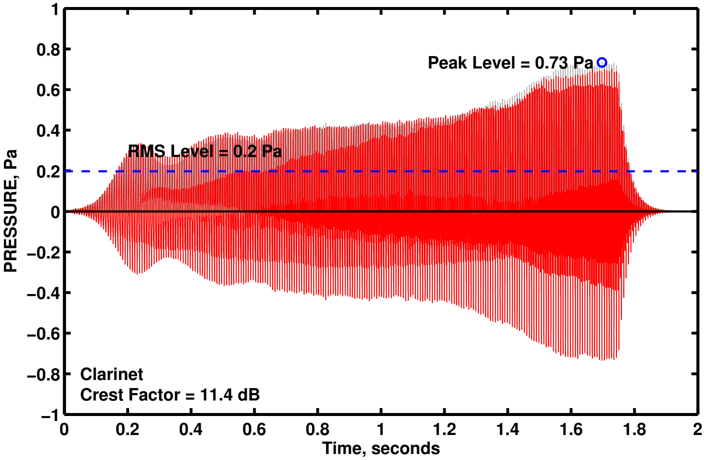
Level Features: dynamics



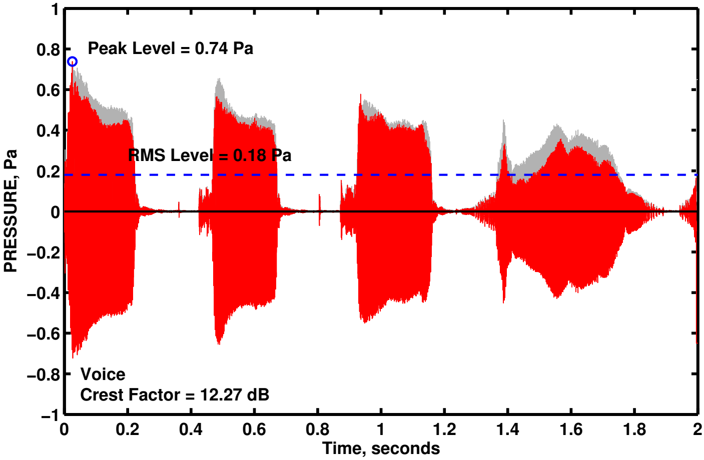
Level Features: dynamics



Level Features: dynamics



Level Features: dynamics



Level Features: dynamics

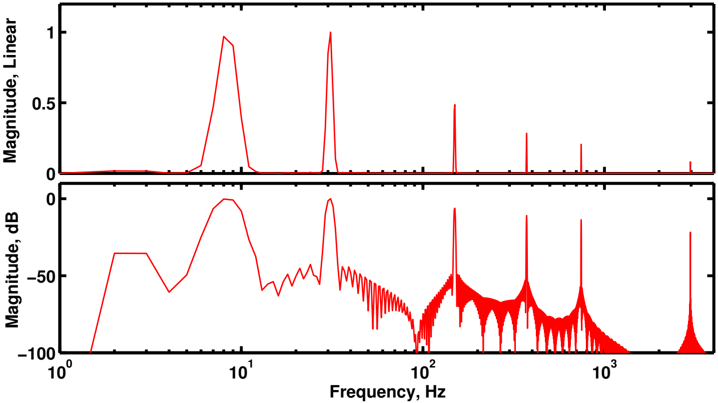
- The **dynamics** are quantified using the **Crest Factor**, which is the logarithmic ratio of **Peak** and **RMS** levels:

$$\textbf{Crest Factor} = 20\log_{10}\left(\frac{\textbf{Peak}}{\textbf{RMS}}\right) \quad (2)$$

- High Crest Factor $\rightarrow$ Transient.
- Low Crest Factor $\rightarrow$ Steady-state.

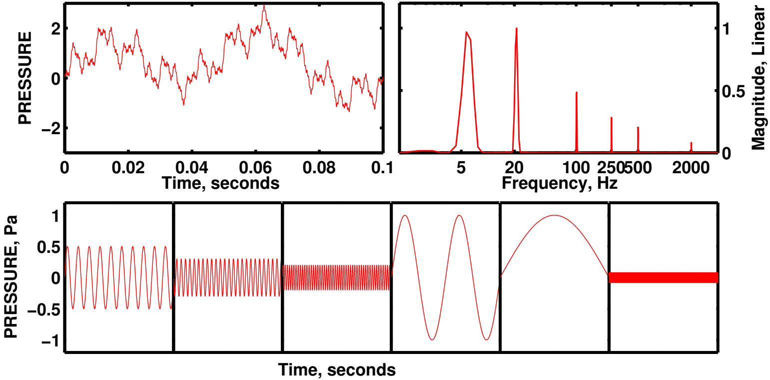
Spectral Features

The frequency spectrum of a sound tell us how the energy within the sound is divided into different frequencies.



Spectral Features

The spikes on the spectrum relate to the individual sine waves from which the sound was composed:



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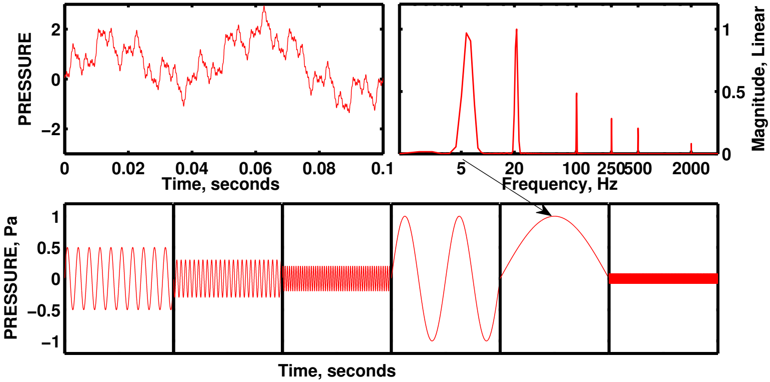

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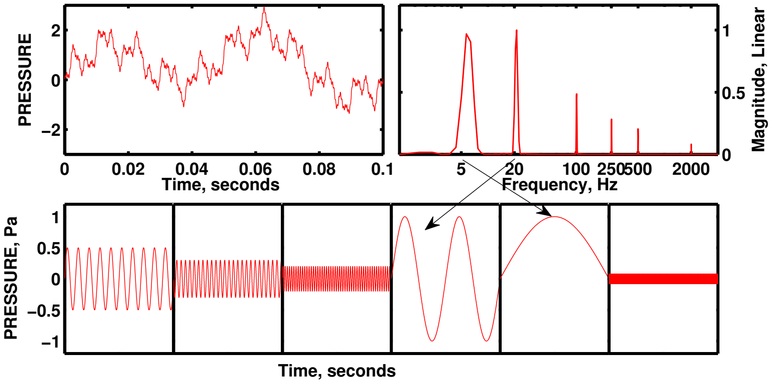

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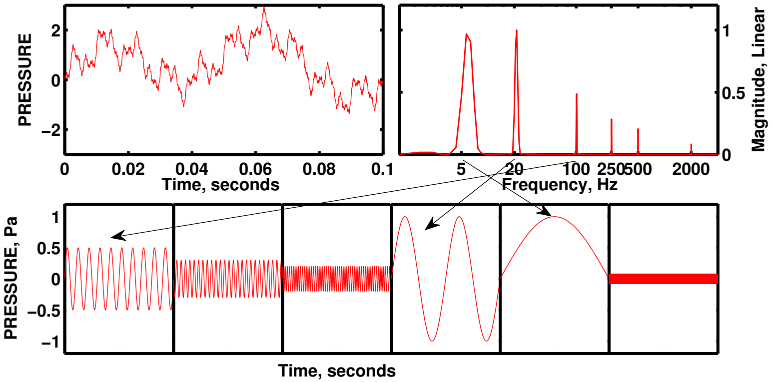

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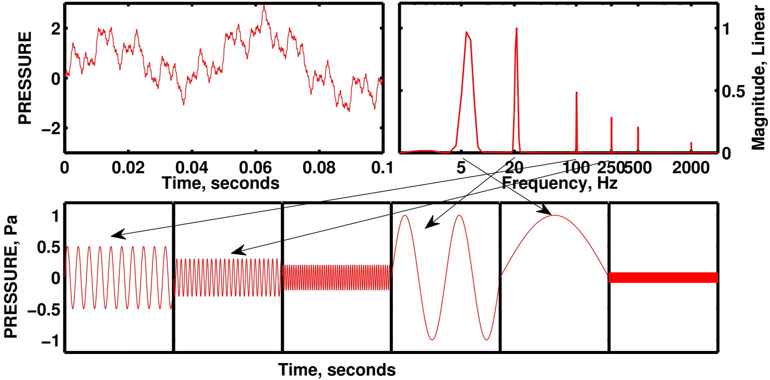

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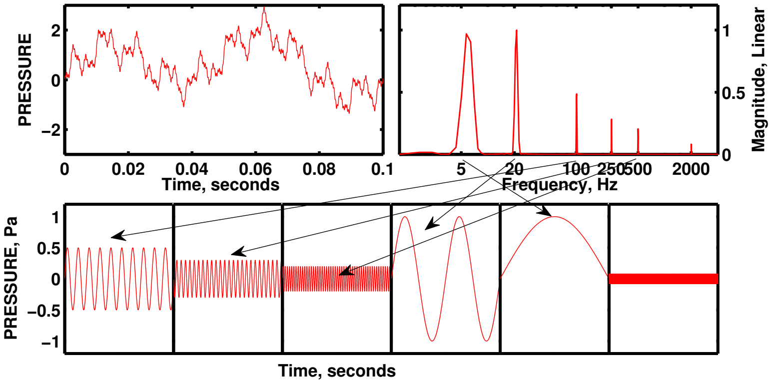

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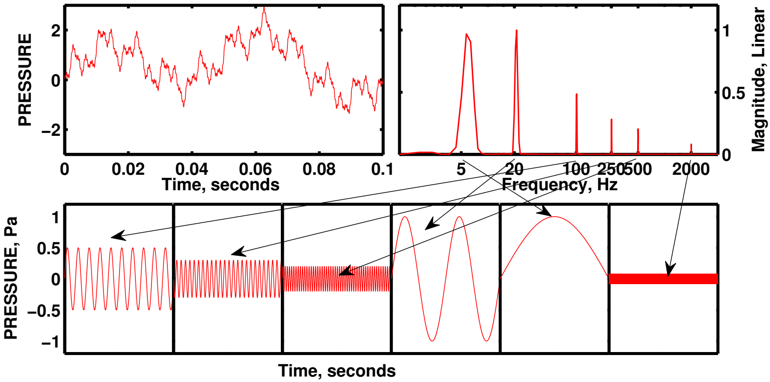
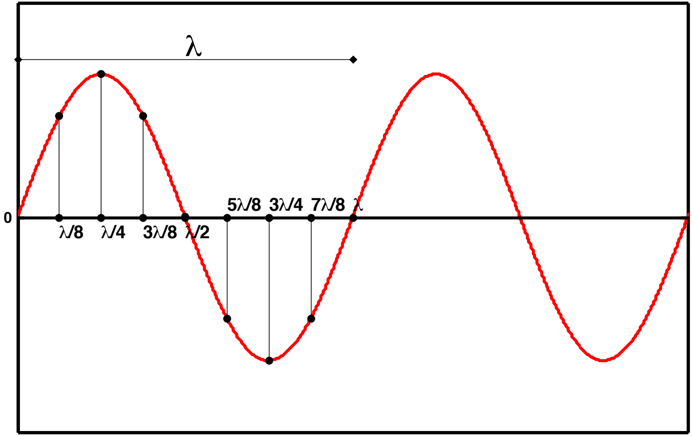


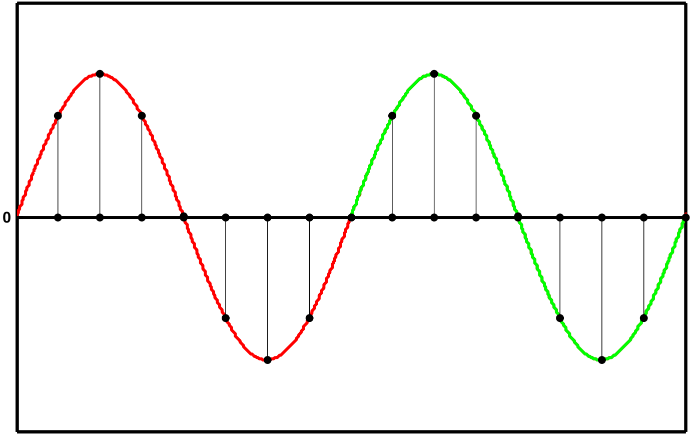
Wave phase

- The position within a cycle of a wave is called the phase and it is defined as a fraction of the wavelength.



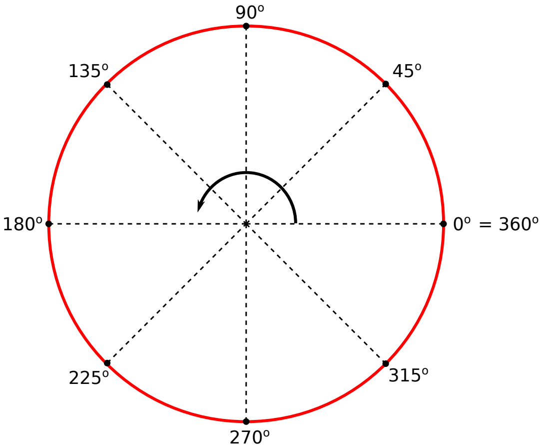
Wave phase

- The positions are repeated at subsequent cycles of the wave.



Wave phase

- The wave phase can be represented on a circle, as an angle.

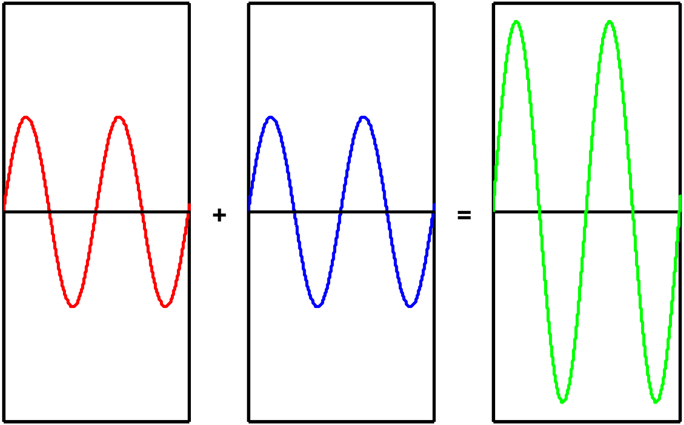


Wave phase

- Why do we care about wave phase as audio people?
- We care, because the **difference** in phase is critical when we are adding waves together, and this is something we do **A LOT** in audio!
- Adding waves: 1 + 1 = **...**?

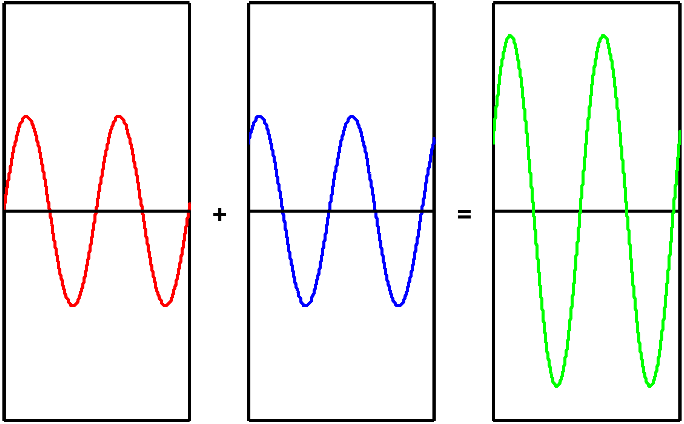
Adding waves - in phase

$\theta = 0^o : 1 + 1 = 2$



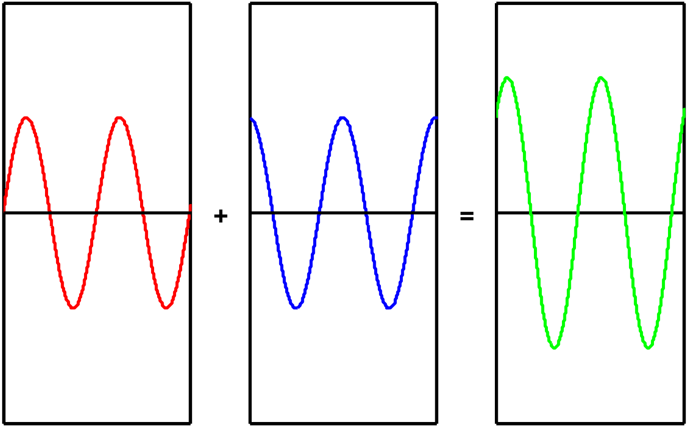
Adding waves - 1/8 cycle

$\theta = 45^{o}$: 1 + 1 = 1.8



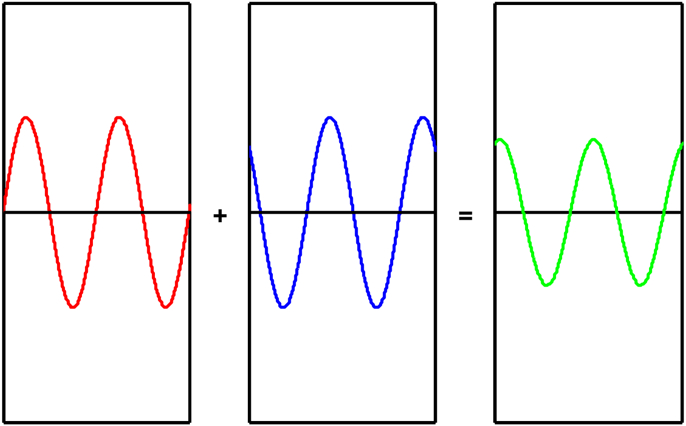
Adding waves - 1/4 cycle

$\theta = 90^{o} : 1 + 1 = 1.4$



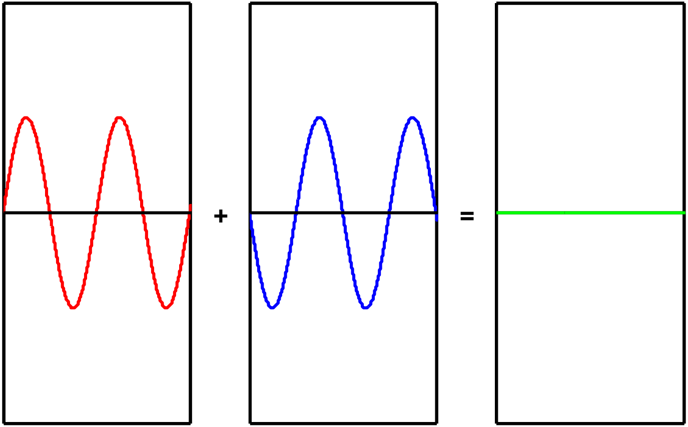
Adding waves - 3/8 cycle

$\theta = 135^o : 1 + 1 = 0.8$



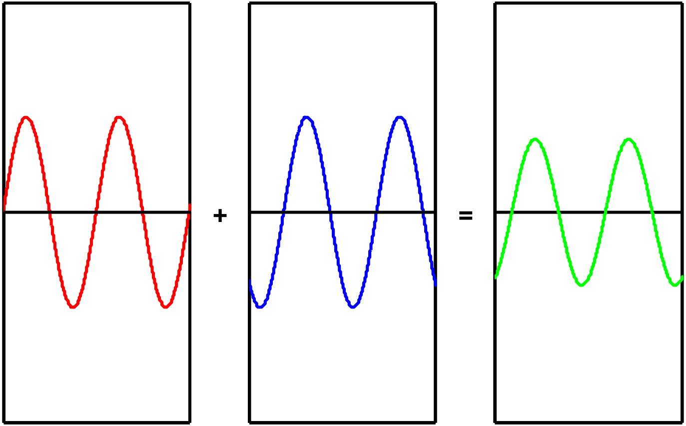
Adding waves - out of phase

$\theta = 180^{o} : 1 + 1 = 0$



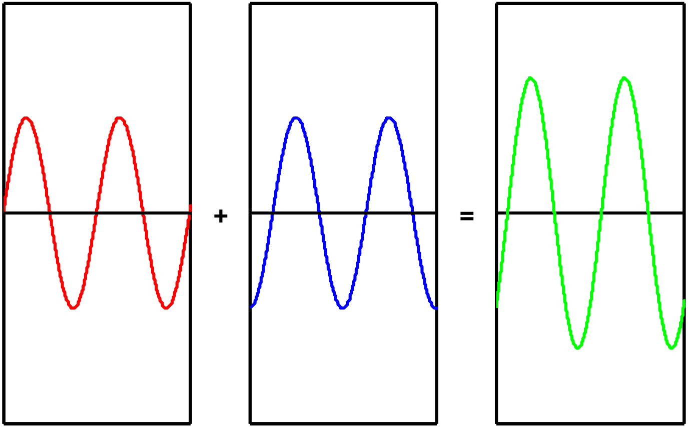
Adding waves - 5/8 cycle

$\theta = 225^{o}$: 1 + 1 = 0.8



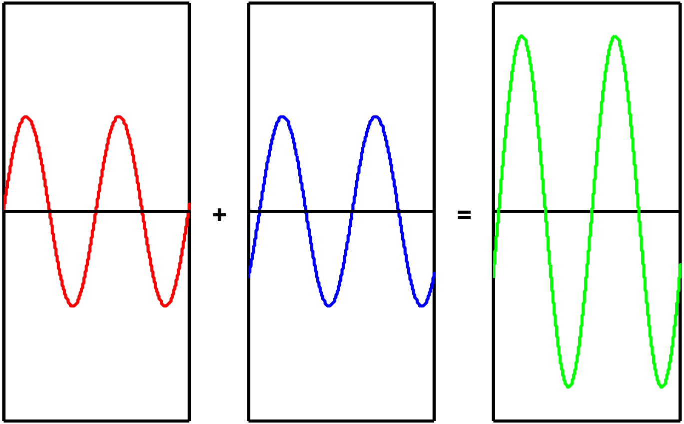
Adding waves - 3/4 cycle

$\theta = 270^{o} : 1 + 1 = 1.4$



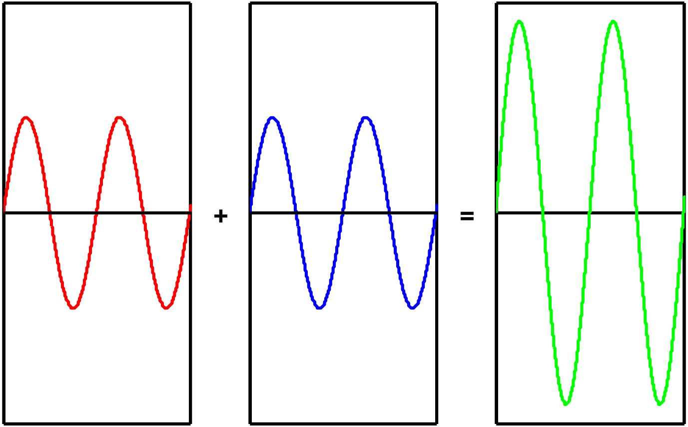
Adding waves - 7/8 cycle

$\theta = 315^o : 1 + 1 = 1.8$

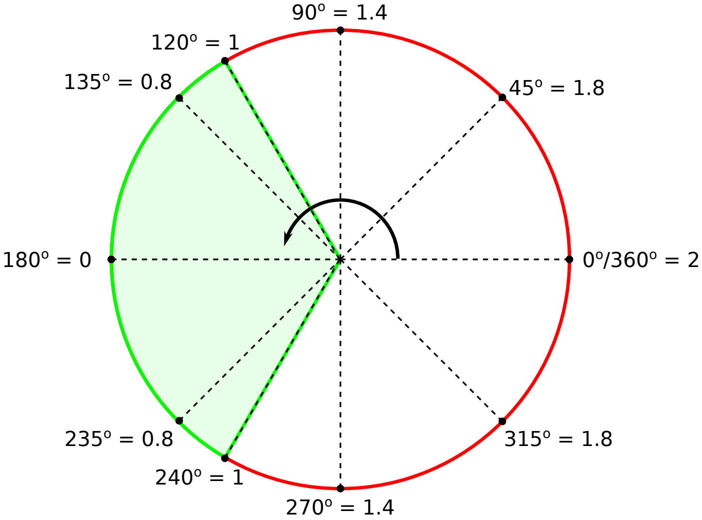


Adding waves - back in phase

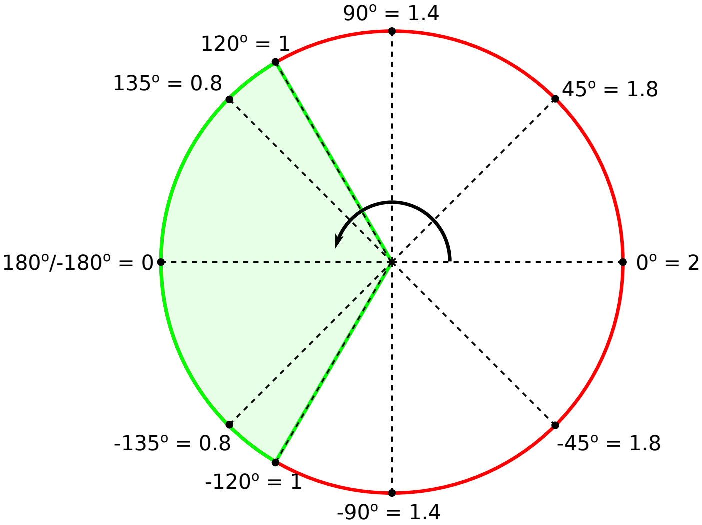
$\theta = 360^{o} : 1 + 1 = 2$



Adding waves

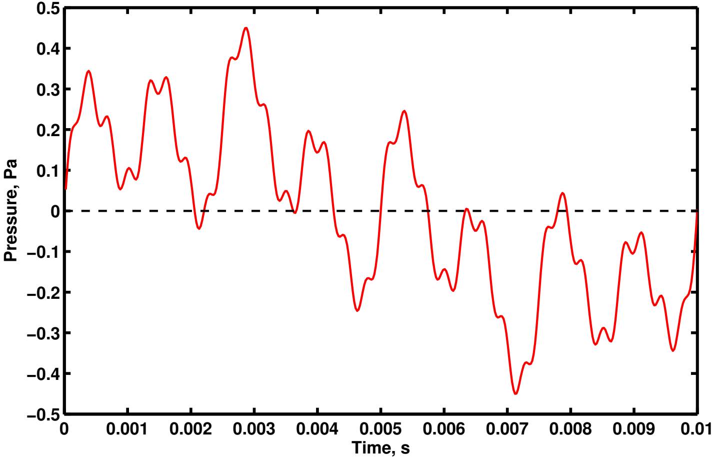


Adding waves



Inverting Phase

Phase is inverted when we ‘flip’ the signal across the time axis.



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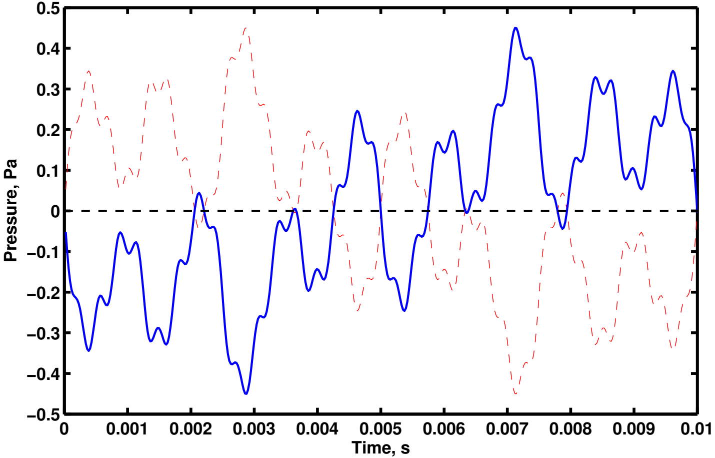
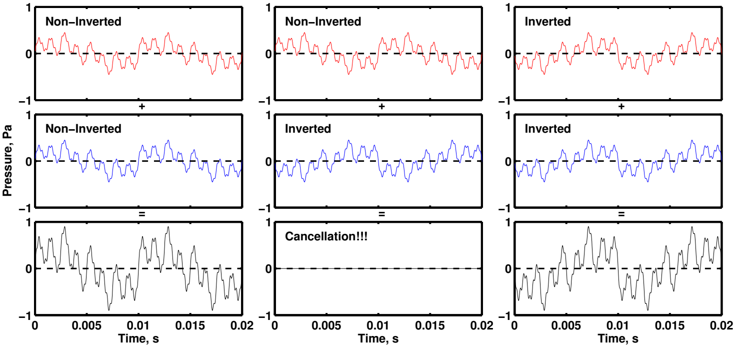


Inverting Phase

Adding inverted and non-inverted signals causes cancellation!

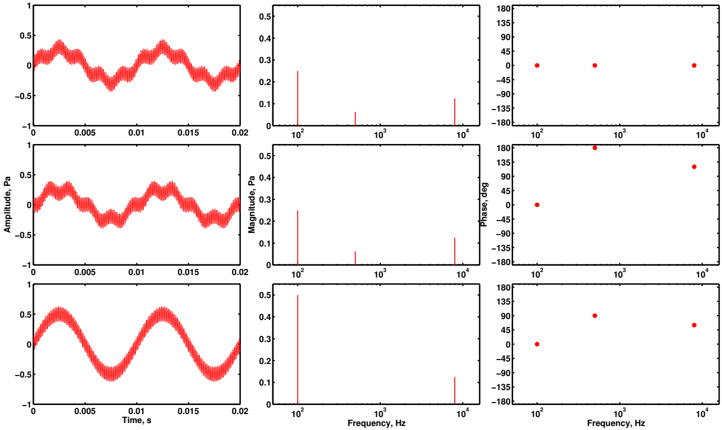


Phase change with frequency

- Phase differences between two sounds can vary as a function of frequency.
- You cannot hear the difference in phase when the signal is played in isolation, but you will hear it when two signals are added together!

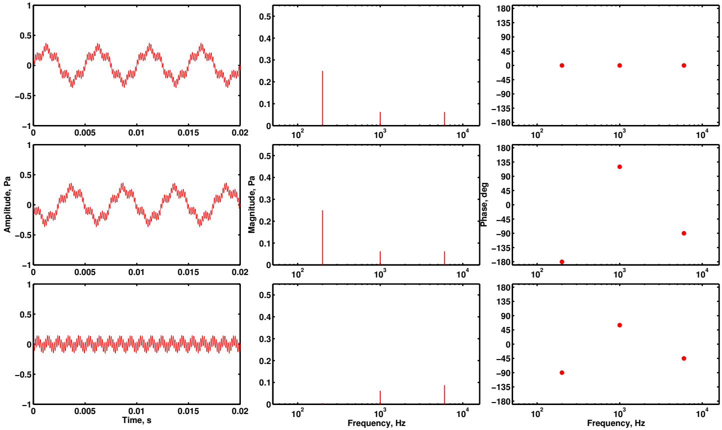
Phase change with frequency

Sound A:



Phase change with frequency

Sound B:



Phase changes due to time delay

- If two sounds are added with a time offset there will be a frequency dependent phase difference.
- A time delay of τ ms is added and can be expressed as a percentage of the time period, **T**, to give a phase shift.

$$\theta = \frac{\tau}{\mathbf{T}} \times 360.$$

Phase changes due to time delay

- What happens if we add a delayed copy of Sound A to the original?
- Sound A has frequency components: $\mathbf{F_1} = 100$ Hz, $\mathbf{F_2} = 500$ Hz and $\mathbf{F_3} = 8000$ Hz.
- These relate to time periods: $\mathbf{T_1} = 10$ ms, $\mathbf{T_2} = 2$ ms Hz and $\mathbf{T_3} = 0.125$ ms.

Phase changes due to time delay

- If $\tau = 1$ ms:

$$\theta_1 = \frac{1}{10} \times 360 = 36^o. \quad (3)$$

$$\theta_2 = \frac{1}{2} \times 360 = 180^o. \quad (4)$$

$$\theta_3 = \frac{1}{0.125} \times 360 = 2880^o = 0^o. \quad (5)$$

Phase changes due to time delay

The effect of $\tau = 1$ ms plotted against frequency: referred to as a comb filter.