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Learning Outcomes

- Understand how waveforms, spectra and spectrograms can be used to view sound signals.

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Characteristics of Sound

1. Amplitude of displacement

Air molecule

Sound Force

- maximum displacement + maximum displacement

QUIET SOUND – SMALL DISPLACEMENT

LOUD SOUND – LARGE DISPLACEMENT

(rather than air molecule displacement we usually talk about sound pressure as the measure of sound amplitude)

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Characteristics of Sound

2. Period (T)

unit of measure: seconds (s)

Air molecule

- maximum displacement + maximum displacement

period (T) = time taken to complete one cycle

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Characteristics of Sound

3. Frequency (f)

- unit of measure: Hertz (Hz)
- 1 Hz = 1 cps

Air molecule

- maximum displacement + maximum displacement

frequency (f) = number of cycles per second

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Period & Frequency

- Period = time required to complete one cycle (seconds per cycle)
- Equations: $T = 1/f$, or $f = 1/T$
- Thus frequency (f) and period (T) are related
- It is an inverse relationship: the larger the period, the slower the cycle, and the fewer cycles per second

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Sine Wave

- If we have a single 'pure-tone' whistle then we have just one frequency of vibration

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Spectrum

- We can represent the frequency on a spectrum

The diagram consists of two graphs. The left graph, labeled 'WAVEFORM', shows a sine wave with 'AMPLITUDE' on the vertical axis and 'Time' on the horizontal axis. The right graph, labeled 'SPECTRUM', shows a single vertical line representing a frequency component, with 'AMPLITUDE' on the vertical axis and 'FREQUENCY' on the horizontal axis. A label 'Single frequency present' points to this line.

Complex periodic sounds

- Complex periodic sounds have a repetition frequency (fundamental) and higher frequency components at multiples of the fundamental (harmonics)

The diagram shows a complex periodic waveform on the left and its spectrum on the right. The spectrum has 'AMPLITUDE' on the vertical axis and 'FREQUENCY' on the horizontal axis. It shows a series of vertical lines representing frequency components. The lowest line is labeled 'fundamental' and the subsequent lines are labeled 'harmonics'.

Complex periodic sounds

This slide compares three waveforms and their spectra. For each waveform (Sine, Sawtooth, Square), there is a 'Waveform' plot and a 'Spectrum' plot. The 'Sine' spectrum shows a single line for the 'fundamental'. The 'Sawtooth' spectrum shows multiple lines for 'fundamentals' and 'harmonics'. The 'Square' spectrum also shows multiple lines for 'fundamentals' and 'harmonics'.

Spectrograms

- To view the changes in the speech spectrum through time we use a spectrogram
- This shows the acoustic energy at each frequency and time
- The darker the display, the more energy is present at that frequency
- Allows us to view the dynamic changes in the speech spectrum

Spectrogram example – three whistles

A screenshot of a spectrogram software interface. The top part shows a waveform of three whistle sounds. The bottom part shows the corresponding spectrogram, with frequency on the vertical axis and time on the horizontal axis. The spectrogram shows three distinct energy bursts corresponding to the whistles.

A detailed spectrogram of a whistle sound. The vertical axis is labeled 'Frequency' and ranges from 0 to 2000 Hz. The horizontal axis is labeled 'Time' and ranges from 0 to 1000 ms. The spectrogram shows a series of horizontal lines representing harmonics. A label '10ms period -> 100 cycles per second repetition frequency 100Hz' points to the time axis. Another label 'Fundamental frequency (100Hz)' points to the lowest harmonic line. A third label 'Harmonics (multiples of 100Hz)' points to the higher frequency lines.

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Spectrogram Bandwidth

- Wide-band spectrogram – coarse frequency resolution (smears detail across frequency), rapid time response
- Narrow-band spectrogram – good frequency resolution, poor time-response (smears detail across time)

