Determining speed of sound through Doppler's Effect

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Outline

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- A buzzer moves on circumferential path.
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- Sound analysed; frequency shift measured; velocity of sound calculated.

Apparatus

Required

A buzzer, a recorder and an analyzer (in our experiment, it was my laptop), a bicycle wheel, three 1.5 V batteries.

Picture

Theory

- Doppler shift:

$$f' = \left(\frac{v - v_o}{v - v_s} \right) f$$

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- Doppler shift:
$$f' = \left(\frac{v - v_o}{v - v_s}\right) f$$
- This is for sound waves, **not** light waves.
- Here $v_o = 0$. Observer is the laptop.
-
$$f' = \left(\frac{v}{v - v_s \cos\theta}\right) f$$
$$\Rightarrow \frac{f}{f'} = 1 - \frac{v_s \cos\theta}{v}$$

Theory *contd.*

Two extremes. (Buzzer moving away; Buzzer direct approach)

$$\frac{f}{f_1} = 1 - \frac{v_s}{v}$$

$$\frac{f}{f_2} = 1 + \frac{v_s}{v}$$

Subtract:

$$f\left(\frac{1}{f_2} - \frac{1}{f_1}\right) = \frac{2v_s}{v}$$

Procedure

- Buzzer mounted on the wheel. DC Motor used to rotate it.
- Speed of buzzer estimated (5.17 m/s). Radius of wheel 0.32 m.

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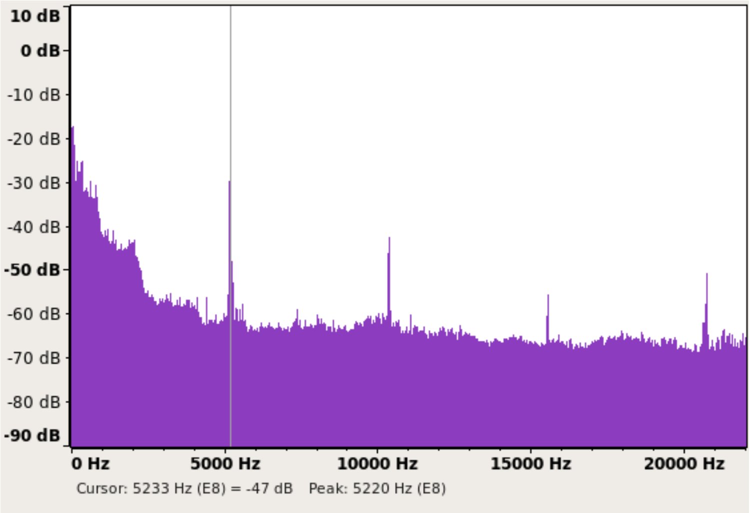
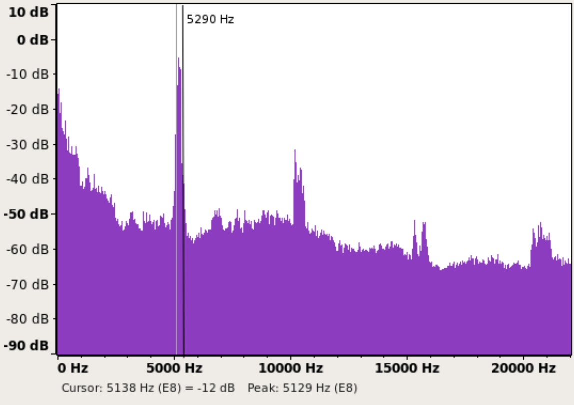
- Buzzer mounted on the wheel. DC Motor used to rotate it.
- Speed of buzzer estimated (5.17 m/s). Radius of wheel 0.32 m.
- Two sound recordings taken:
  - static condition.
  - while the buzzer is moving.
- FFT of waveforms done, and frequencies detected.

Static



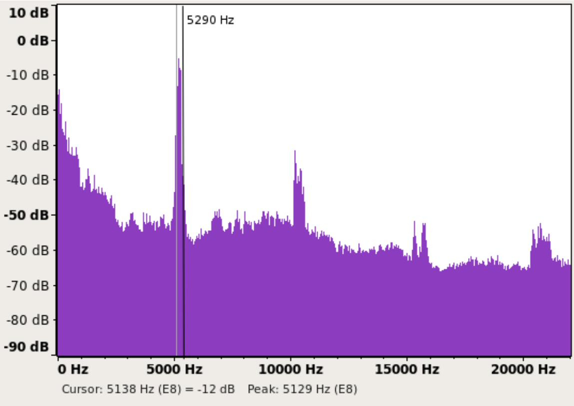
Frequency of buzzer: 5220 Hz. (play sound)

Moving



Two peaks very closely spaced.

Moving



Two peaks very closely spaced. 5129 Hz and 5290 Hz.
These are our f_1 and f_2. (play sound)

Results

Working formula:

$$f\left(\frac{1}{f_2}-\frac{1}{f_1}\right)=\frac{2v_s}{v}$$

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$$\mathrm{v} = 333.8 \text{ m/s}$$

Results

Working formula:

$$f\left(\frac{1}{f_2} - \frac{1}{f_1}\right) = \frac{2v_s}{v}$$

Plugging in the values, we get:

$$\mathrm{v} = 333.8 \text{ m/s}$$

Agrees well with expected value of v $\sim$ 330 m/s.

Endnote

Precautions, Pitfalls

- Original plan: use condensor microphone and PHOENIX. Use the CRO program to analyze.
- failed: Condensor microphone not sensitive enough.

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Precautions

- Constant frequency buzzer; our buzzer's frequency varied a bit.
- The receiver should be sensitive enough.
- Sufficient detail in waveform, for accurate FFT.
- Sound input within allowable range of the microphone used, or we'll get cutoff.

Other things

- Verify speed of sound using some other experiment. (resonance in air column).
- Turn the experiment around; use the speed of sound to find velocity of source.

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Applications

- Measure velocity of train from frequency shift of whistle.
- Light version of Doppler: Extensively used to determine speed of galactic objects.

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References

1. H.C. Verma, Concepts of Physics, Bharati Bhawan, pp 342-344.
2. http://en.wikipedia.org/wiki/Doppler_effect