Urban Physics

7S0X0, 2020-2021 Quartile 3

prof.dr.ir. Maarten Hornikx
dr. Matthias Cosnefroy

EINDHOVEN UNIVERSITY OF TECHNOLOGY

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Urban Acoustics

Week 3 Sources of sound

prof.dr.ir. Maarten Hornikx

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Sources of sound in the urban environment

- Transportation sources
  - Road traffic
  - Railway traffic
  - Aircraft

- Industrial and construction type of sources
  - Wind turbines
  - Industrial activity
  - Shipping ports
  - Construction sites

Sources of sound in the urban environment

TABLE 6.1 Estimated Percentage of Highly Annoyed for Different Noise Sources

	Percentage of Highly Annoyed				
L_{den} [dB(A)]	Road (%)	Rail (%)	Aircraft (%)	Industry (%)	Wind turbine (%)
55	6	4	27	5	26
50	4	2	18	3	13
45	1	0	12	1	6

Murphy, E., & King, E. (2014). *Environmental noise pollution: Noise mapping, public health, and policy*. Newnes.

Basic noise prediction equation

$$L_p = E - A_{tot} + C$$

L_p	Sound pressure level at a receiver point
E	Source power term (= L_w in week 1)
A_{tot}	Attenuation term (total amount of sound attenuation occurring between source and receiver: includes ground attenuation, atmospheric attenuation, attenuation through geometric divergence and attenuation by diffraction around noise barriers)
C	Correction term: e.g. reflections from a facade, different road surfaces or train track types

Basic noise prediction equation

$$L_p = E - A_{tot} + C$$

E Source power term (= L_w in week 1) dependent on:

Source type

Frequency

Angle to source (directivity)

Height of source above ground

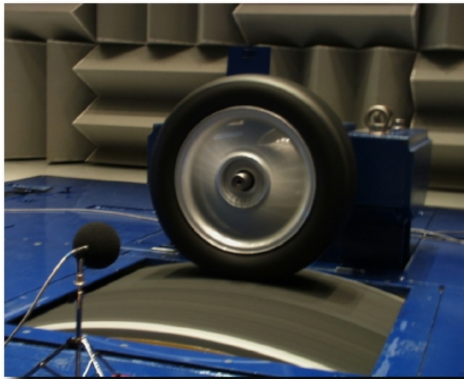
Road traffic: source mechanisms

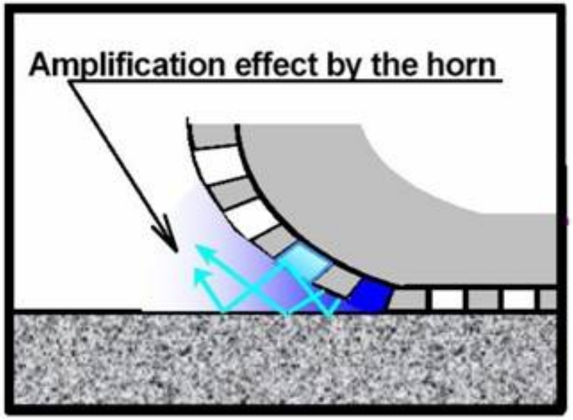
- Most dominant source of environmental noise

- Rolling noise. Influencing aspects
  - Impact from tyre to road
  - Aerodynamic noise
  - Vibrations of the tyre tread
  - ‘stick–slip’ friction between the tyre and the road

+

Horn effect





https://www.tut.fi

Road traffic: source mechanisms

- Most dominant source of environmental noise

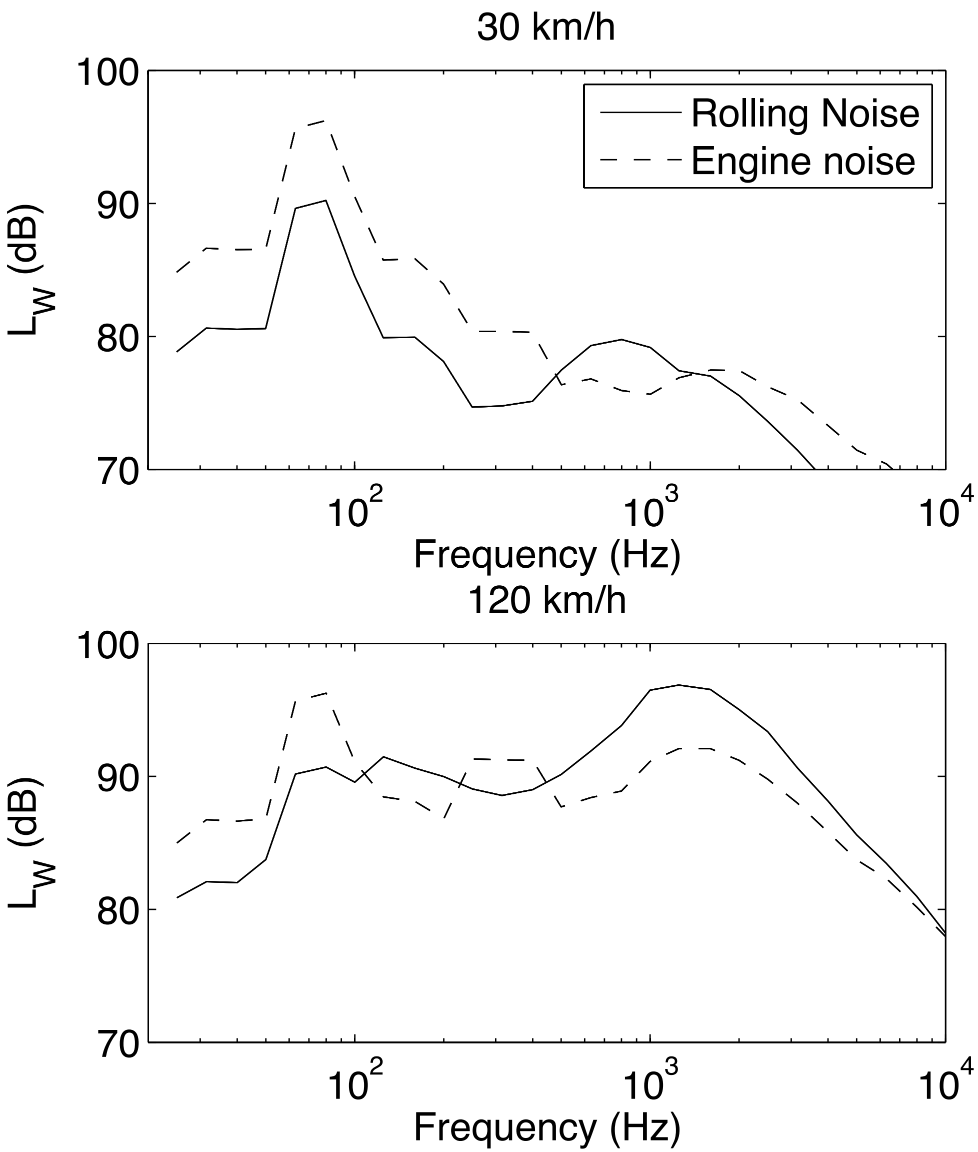
- Rolling noise. Influencing aspects
  - Impact from tyre to road
  - Aerodynamic noise
  - Vibrations of the tyre tread
  - ‘stick–slip’ friction between the tyre and the road

- Engine noise. Subsources
  - Combustion engine
  - Aerodynamic noise (in pipe system)

Road traffic: source mechanisms

- Spectra for lightweight vehicles

- Low frequency noise: engine
- High frequency noise: tyre-road noise



Calculation according to HARMONOISE source model

Rail traffic noise: source mechanisms

Second Most dominant source of environmental noise

- Rolling noise

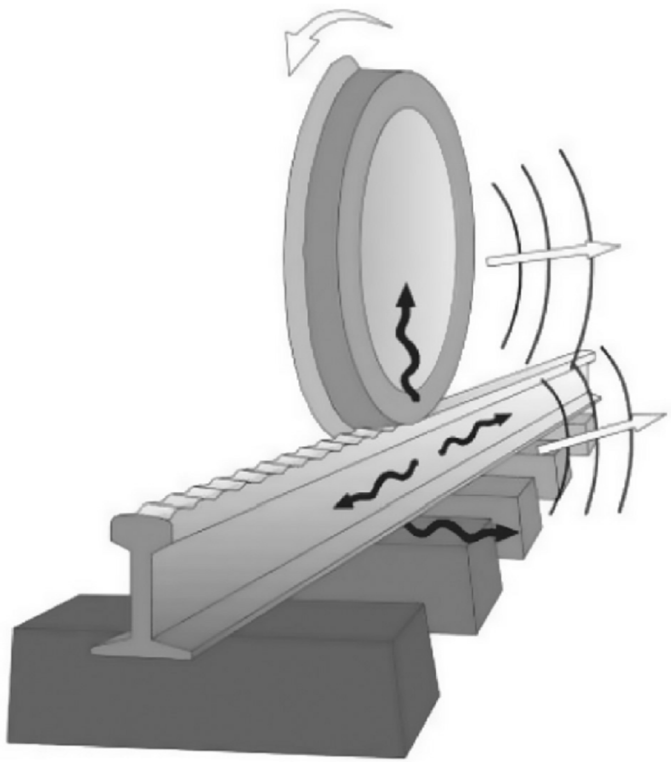
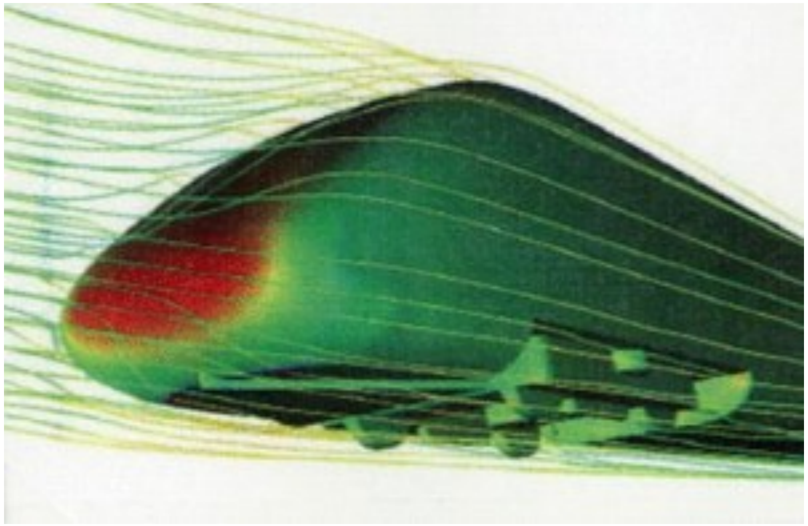


FIGURE 5.7 The mechanisms behind the generation of rolling noise.

Murphy, E., & King, E. (2014). *Environmental noise pollution: Noise mapping, public health, and policy*. Newnes.

Rail traffic noise: source mechanisms

- Engine noise
  - Exhaust noise
  - Noise from fans and cooling system
  - Engine and transmission vibrations
- Aerodynamic noise
  - Flow induced noise



http://www.raillynews.com

Rail traffic noise

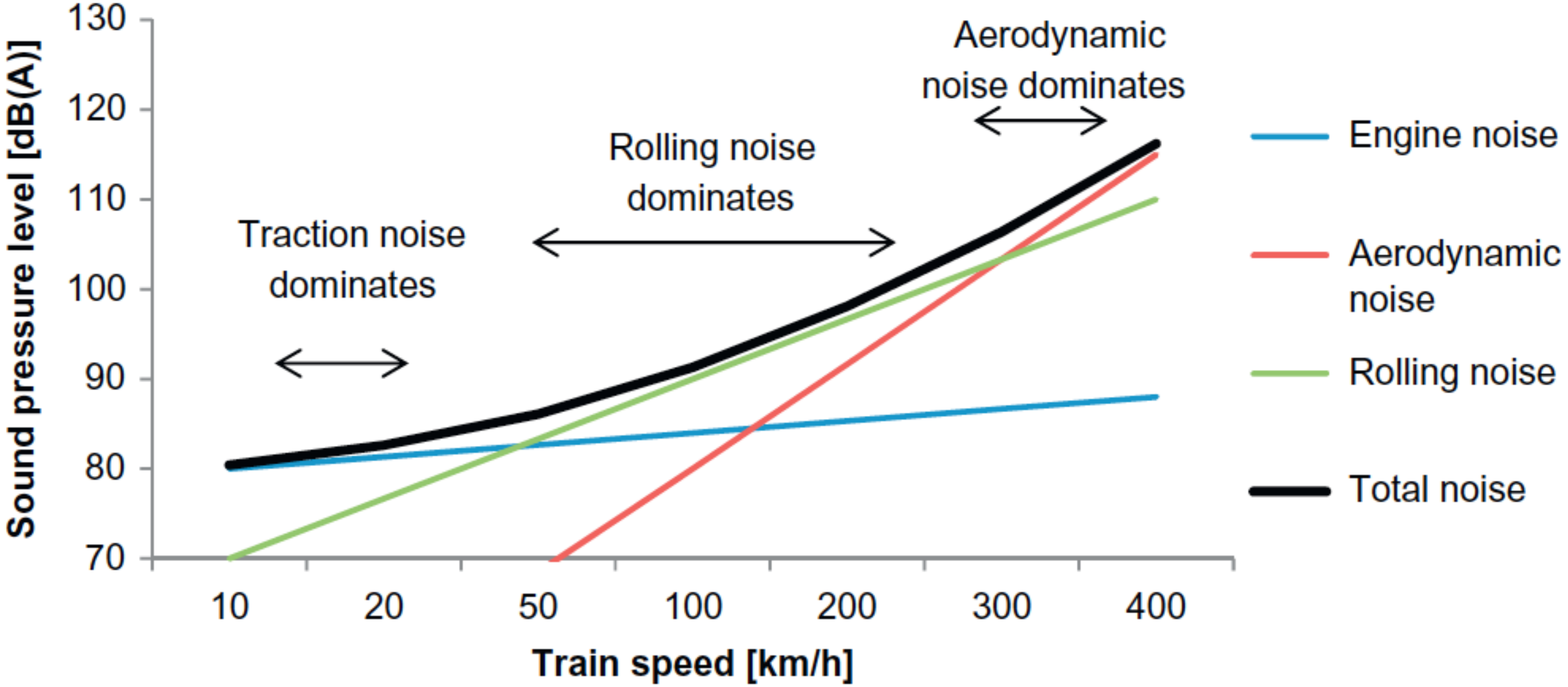


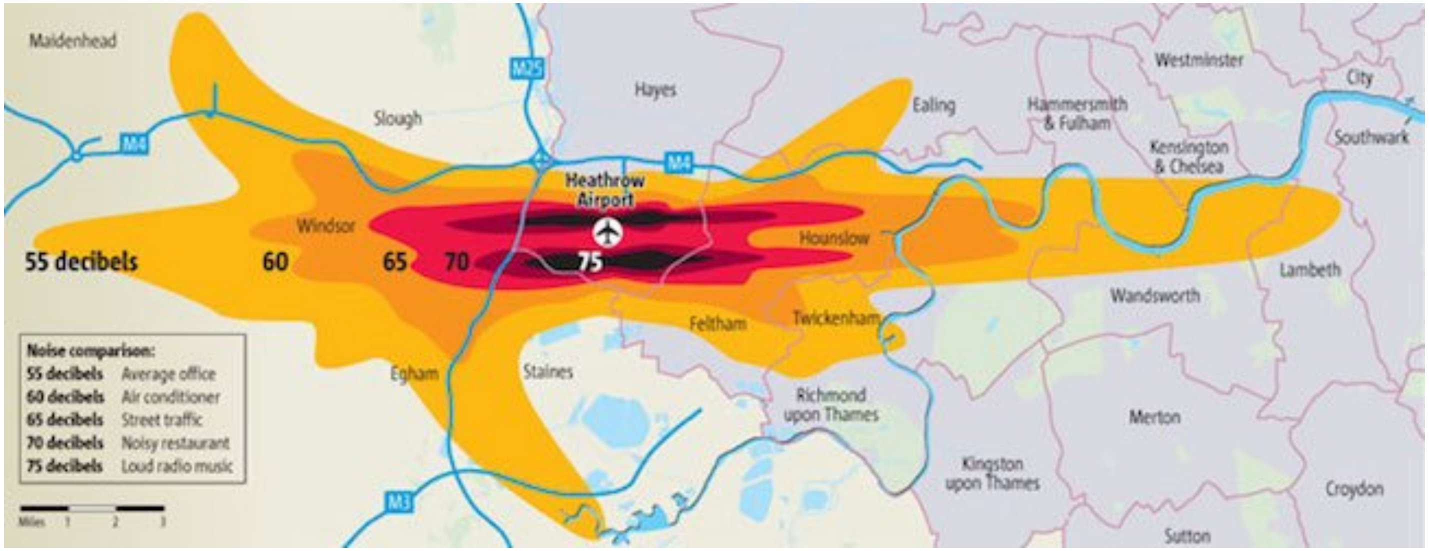
FIGURE 5.6 Approximate Relationship of different railway noise source mechanisms with speed. *Adapted from de Vos (2012).*

Murphy, E., & King, E. (2014). *Environmental noise pollution: Noise mapping, public health, and policy*. Newnes.

Aircraft noise

- Aircraft noise affects a much smaller proportion of the population compared to road and traffic noise
- However, aircraft noise has probably received greater attention in the media and among the general public compared to other noise sources. This is most likely because aircraft noise is regarded as the most annoying source of transportation noise.
- Included in END noise maps

http://webtrak5.bksv.com/lhr4



Aircraft noise

NLTIMES.NL TOP STORIES CRIME POLITICS BUSINESS SPORTS FOOD HEALTH WEIRD TECHNOLOGY ENTERTAIN

BUSINESS

LELYSTAD AIRPORT OPENING DELAY A BLOW TO SCHIPHOL, BUDGET AIRLINES

By Janene Pieters on February 21, 2018 - 12:00

https://nltimes.nl/2018/02/21/lelystad-airport-opening-delay-blow-schiphol-budget-airlines

Aircraft noise

- Jet engine noise: interaction of the high-velocity exhaust gasses with the relatively still atmosphere through which the aircraft passes; as the gasses mix, the resulting turbulence creates large pressure fluctuations
- Aerodynamic noise sources. Flow induced noise influenced by
  - Nacelles (the cover in which the engine is housed)
  - Wings
  - Landing gear

  - Different characteristics for different flight stages

Wind turbine noise

- Noise maps have not been developed for wind farms in the context of the END
- Noise is often reported as the most annoying aspect of wind farm developments

Wind turbine noise

- Sources:
  - Mechanical
  - Aerodynamical

Increase of source power with wind speed

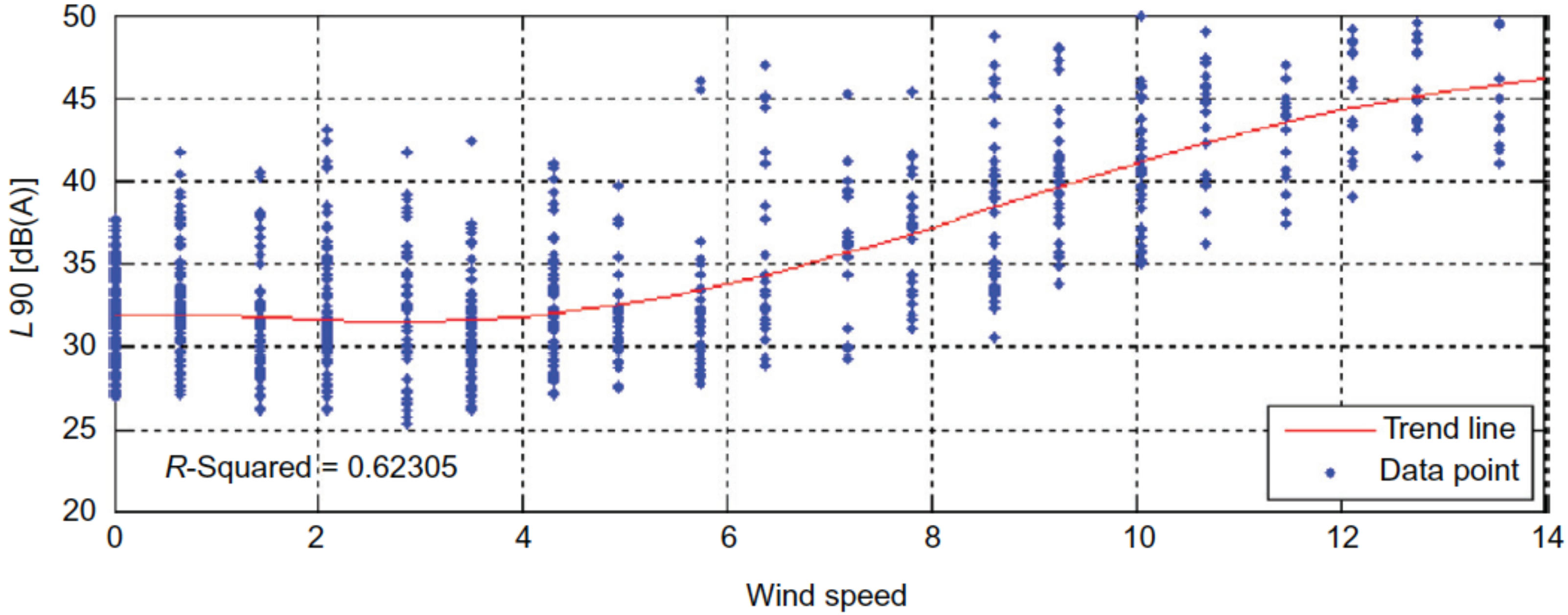
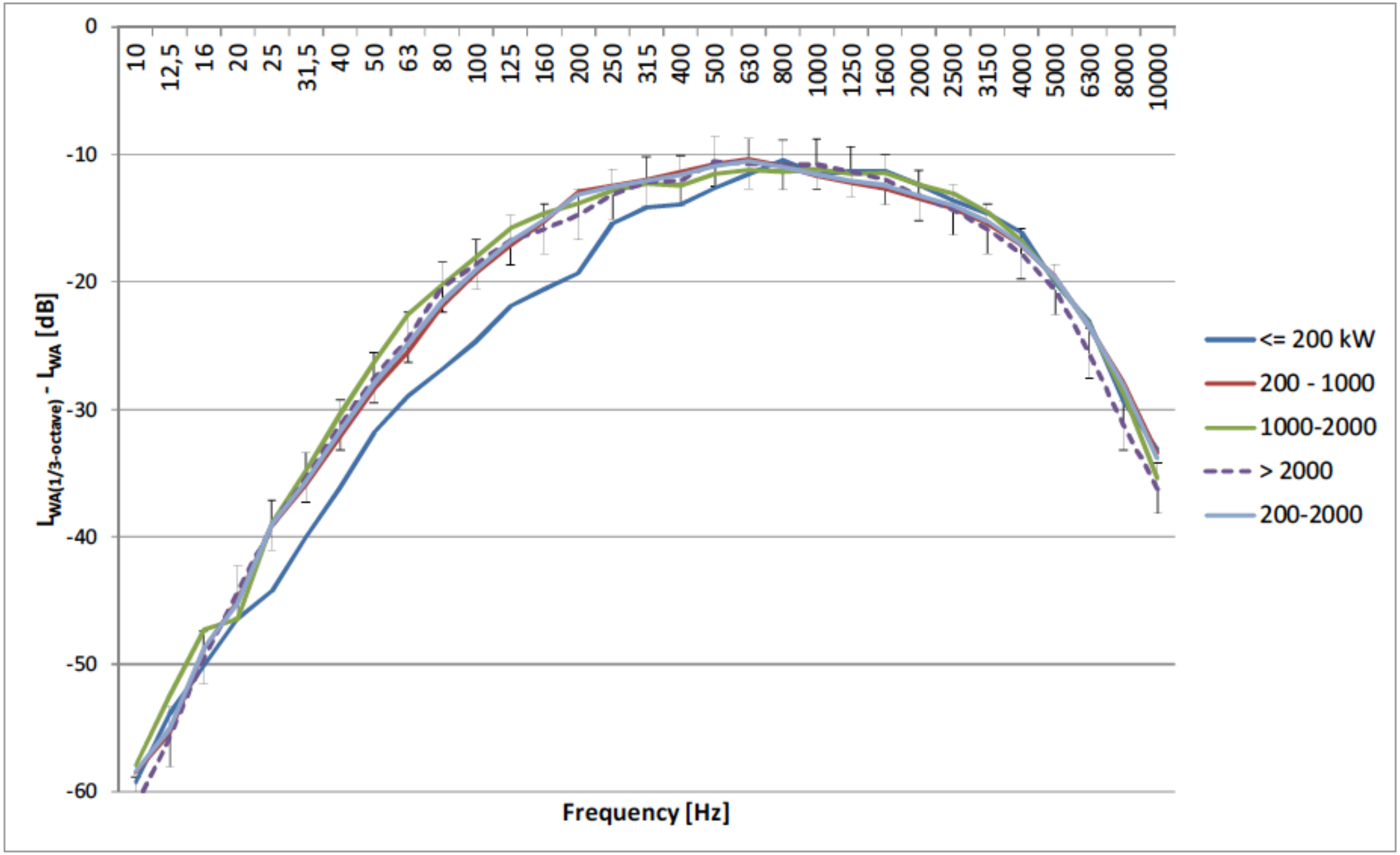


FIGURE 6.4 Example result from a background noise survey relating the background noise level with wind speed.

Murphy, E., & King, E. (2014). *Environmental noise pollution: Noise mapping, public health, and policy*. Newnes.

Wind turbine noise



Sondergaard, B. Noise and Low frequency noise from Wind Turbines, InterNoise 2014, Melbourne Australia

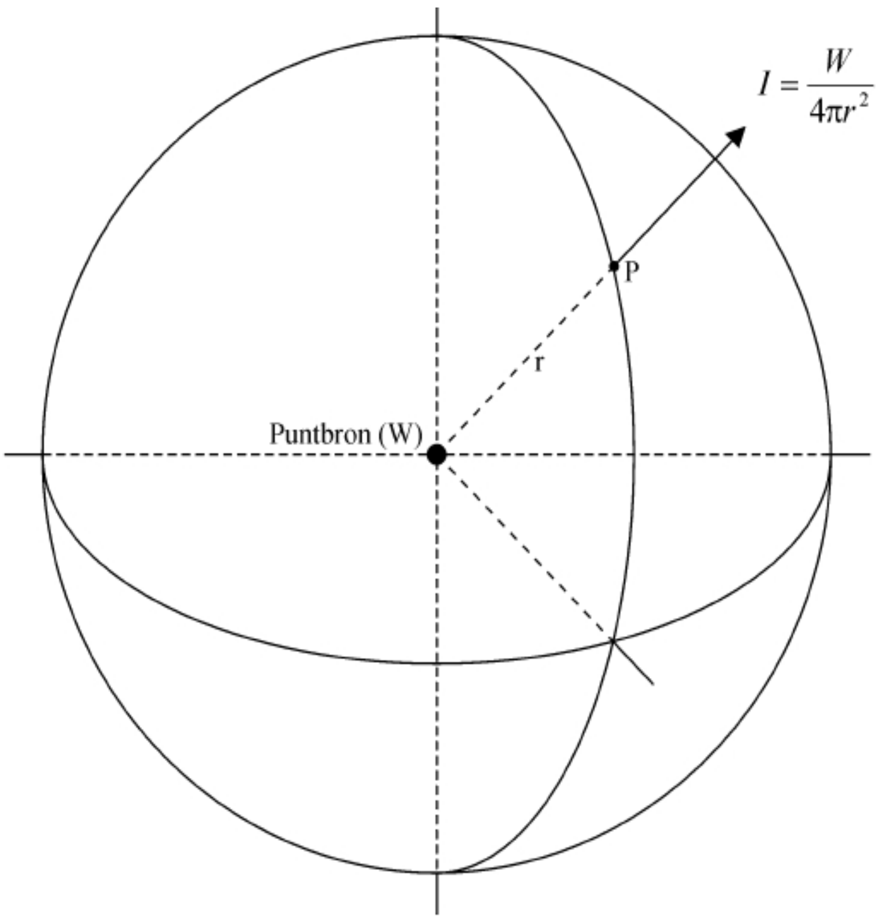
Representing noise sources

Point Source

Line Source

Plane Source

Point source



At distance r from point source:

Sound pressure p is constant

Sound intensity I perpendicular to wave front is constant

Sound power P is constant for all distances r from the point source.

Point source

$$L_p = 10\log_{10}\left(\frac{\frac{1}{T_{\text{int}}}\int_0^{T_{\text{int}}} p^2(t)dt}{p_{ref}^2}\right) = 10\log_{10}\left(\frac{p_{eff}^2}{p_{ref}^2}\right)[\text{dB}]$$

In free field

$$L_p = E - A_{tot}$$

What is A_{tot} for a point source?

-> We should relate L_p to E, or the sound pressure p to the sound power P

Point source

-> We should relate L_p to E, or the sound pressure p to the sound power P

Power of source P [W] can be computed by integrating the acoustic intensity I [W/m^2] over a sphere

$$P_{eff} = \int_S \left(I_{eff} \cdot \vec{n} \right) dS$$

For a point source, this equals to

$$P_{eff} = I_{eff} 4\pi r^2$$

Further, we know, at large distance from the source

$$I_{eff} = \frac{p_{eff}^2}{\rho c}$$

Point source

Thus

$$P_{eff} = \frac{p_{eff}^2}{\rho c} 4\pi r^2$$

And the sound pressure level

$$10\log_{10}\left(\frac{p_{eff}^2}{p_{ref}^2}\right) = 10\log_{10}\left(\frac{\rho c}{4\pi r^2}\frac{P_{eff}}{p_{ref}^2}\right)$$

$$10\log_{10}\left(\frac{p_{eff}^2}{p_{ref}^2}\right) = 10\log_{10}\left(\frac{\rho c P_{eff}}{p_{ref}^2}\right) - 10\log_{10}\left(4\pi r^2\right)$$

$$L_p = E - 10\log_{10}\left(4\pi r^2\right)$$

-> 6 dB per distance doubling
(since surface of sphere increases
quadratically with distance r)

Line source

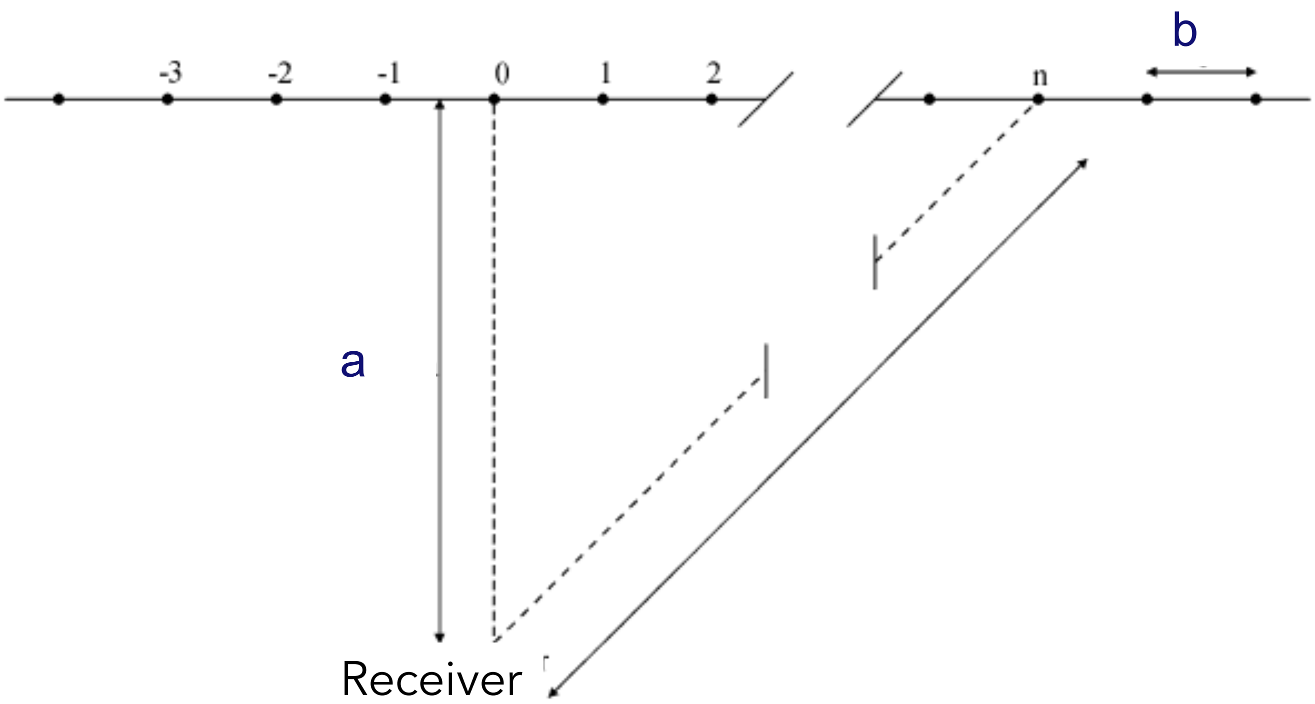
$$P_{eff} = \mathrm{I}_{eff} 2\pi r$$

$$L_p = E - 10\log_{10}(2\pi r)$$

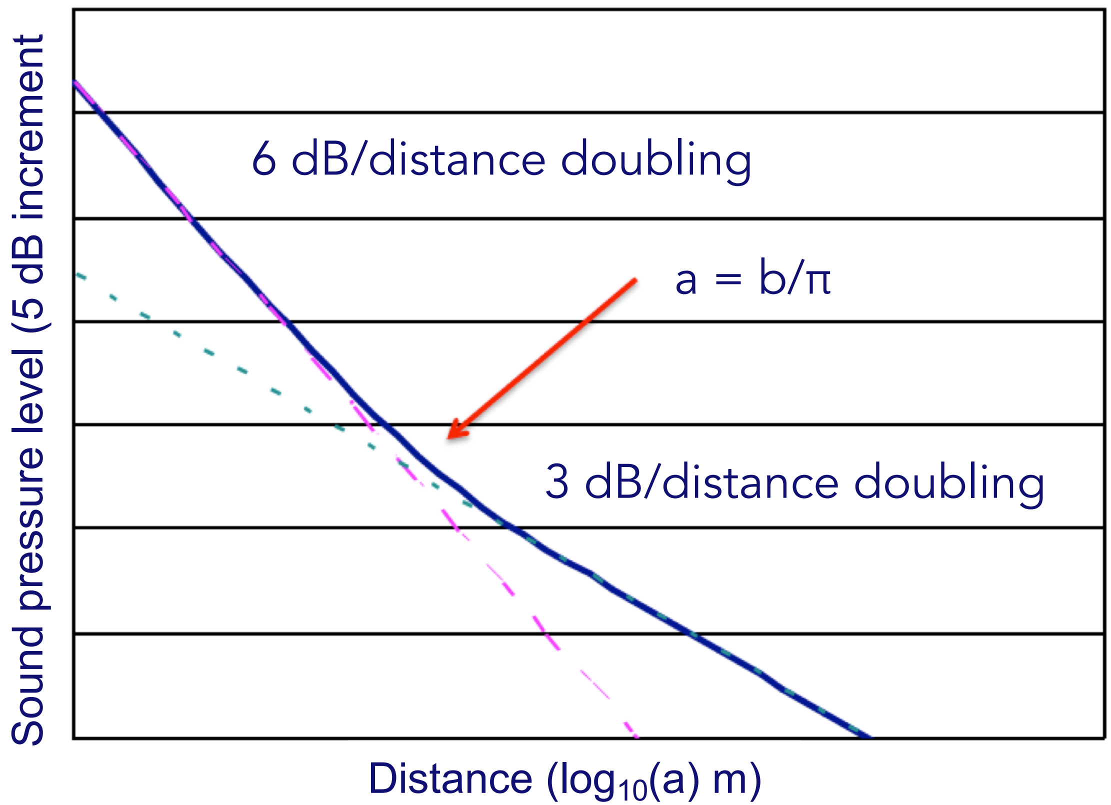
-> 3 dB per distance doubling

Line source

Row of point sources



Line source



6 dB/distance doubling
a = b/π
3 dB/distance doubling
Sound pressure level (5 dB increment
Distance ($\log_{10}$(a) m)

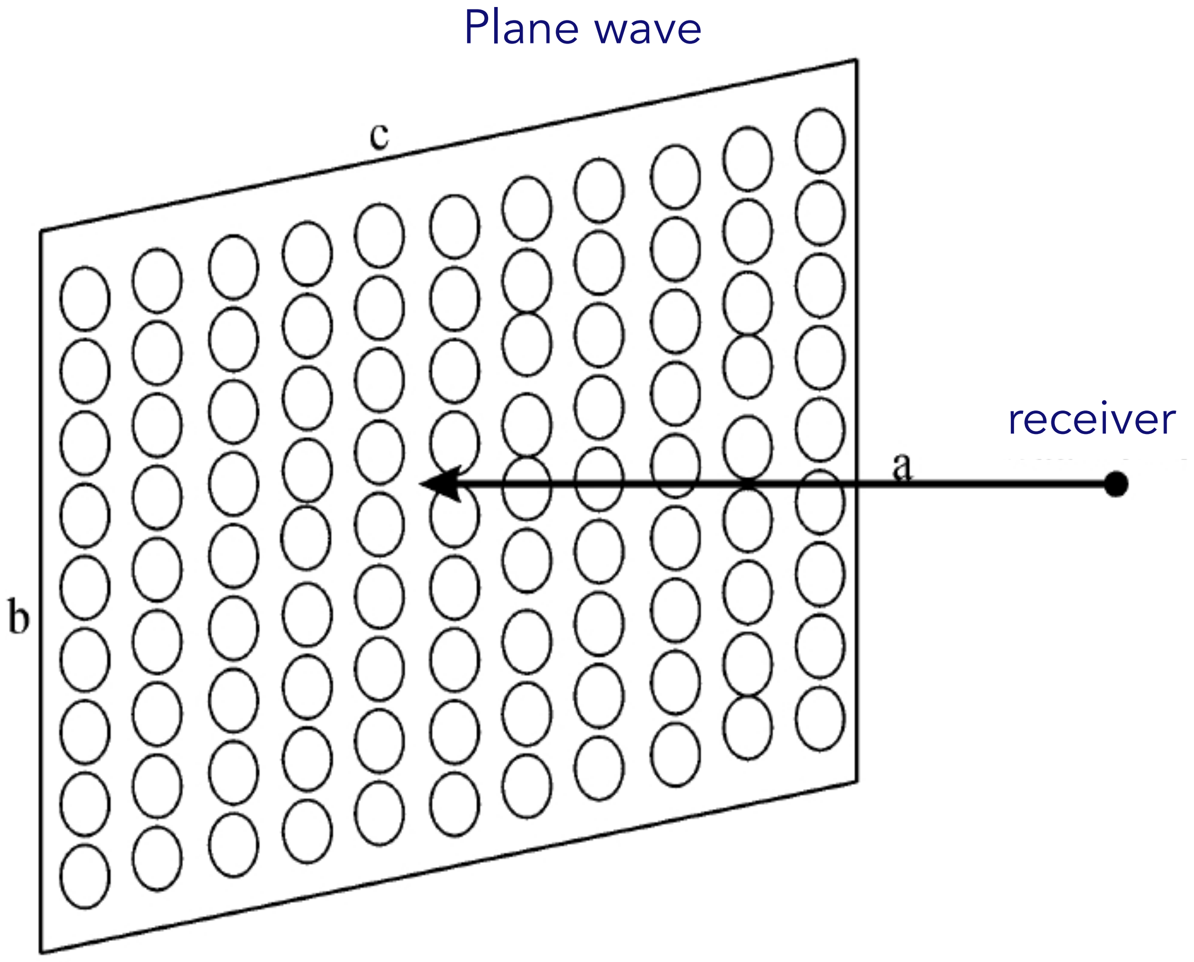
Plane source

$$P_{eff} = \mathrm{I}_{eff} S_{plane}$$

-> 0 dB per distance doubling

$$L_p = E - 10\log_{10}\left(S_{plane}\right)$$

Finite sized – plane source



Finite sized – plane source