

Fundamentals of Environmental Noise Monitoring

CENAC



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Akoustik Engineering
Limited

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Akoustik Engineering Limited

- Akoustik Engineering Limited is the sales and technical representative for Bruel & Kjaer in Ontario.
- Akoustik Engineering is also a full service NVH engineering firm with a combined experience of over 35 years in consulting services and engineering noise abatement design.
- Senior principals have doctorate degrees specializing in noise and vibration control
- Completed over 200 environmental noise and vibration assessment reports and abatement designs
- Typical contracts range from \$5 000 to \$800 000 in value (private sector and all levels of governments)



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Why is it important to consider environmental noise?



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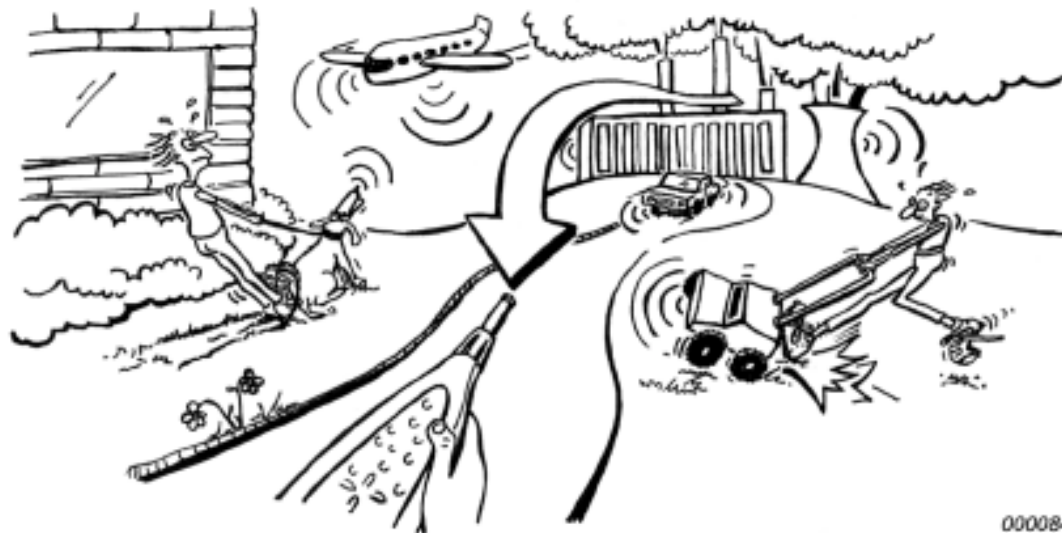
- Studies have shown that approximately 20% of the world population is exposed to unacceptable environmental noise.
- As cities grow, residential areas are encroaching on transportation routes and industrial sources.
- While regulatory requirements are becoming more prominent, many inconsistencies and lack of understanding



Why is it important to consider environmental noise?

The role of the environmental acoustician includes:

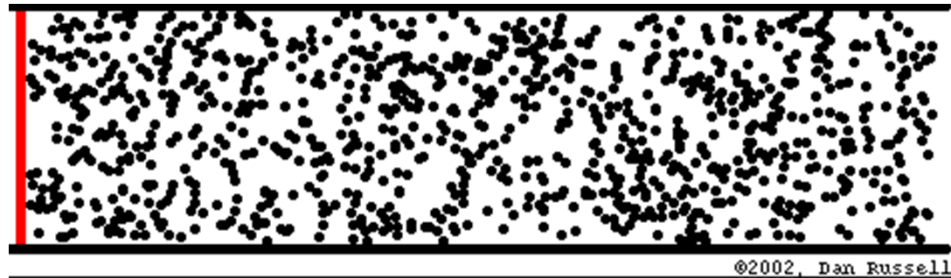
- Conducting noise measurements in the field
- Predicting and/or calculating noise exposure at receptors
- Determining compliance of regulatory guidelines, expert witness
- Designing acoustic abatement
- Addressing annoyance complaints from the public
- City planning for new development and noise mapping of urban areas



What is sound?

What is the definition of sound?

- Sound is the propagation of a disturbance through a medium. For air, sound propagates at the speed of sound or approximately 340 m/s at STP.



How would you define noise?

- Noise is generally considered to be any unwanted sound.
- Environmental Noise is generally referred to as unwanted sound produced by human activities which interfere with communication, work, rest, recreation and sleep.

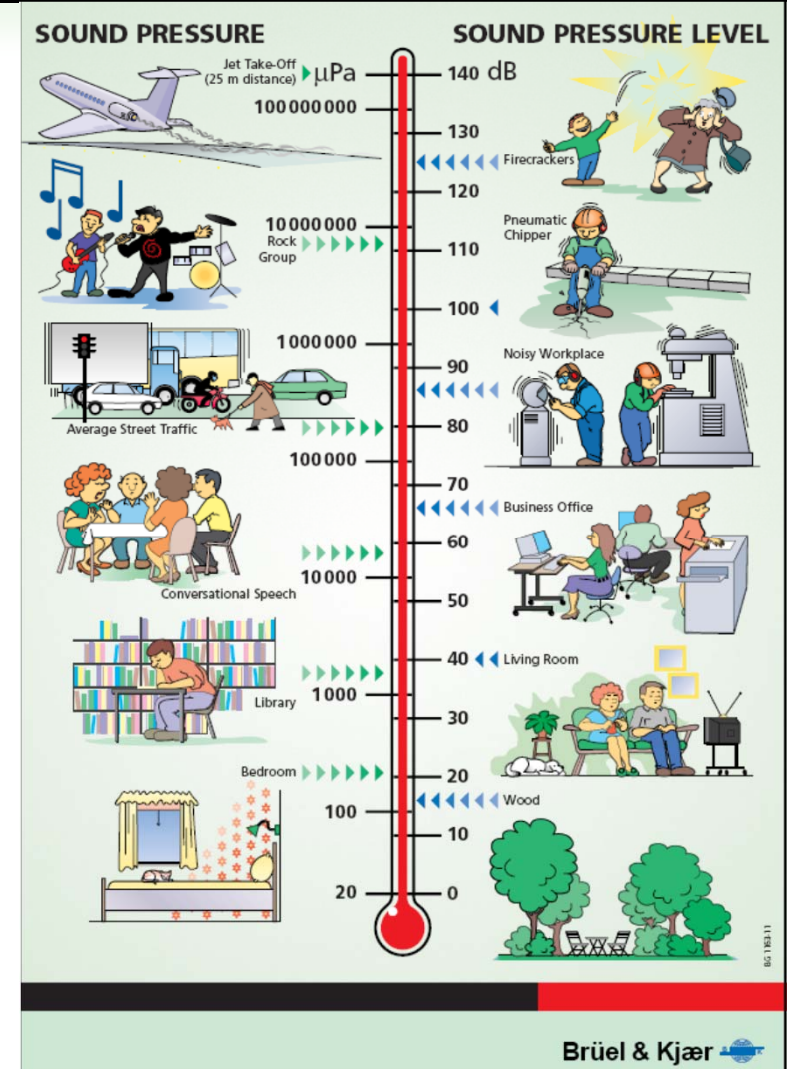
Pressure vs. Pressure Level

- Magnitude of sound pressure affecting the ear varies from 2×10^{-5} Pa at the threshold to 200 Pa at instantaneous damage.
- To account for this, we use a log scale to describe sound pressure level (SPL).

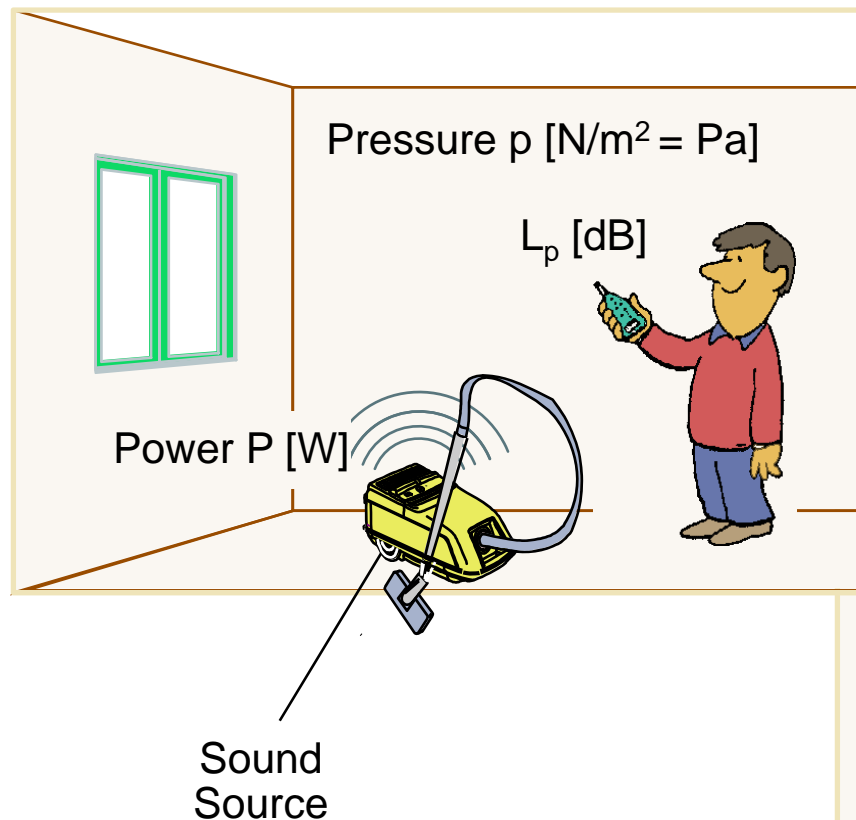
$$SPL = 20 \log(P / P_{ref})$$

Where $P_{ref} = 2 \times 10^{-5}$ Pa
(the threshold of hearing)

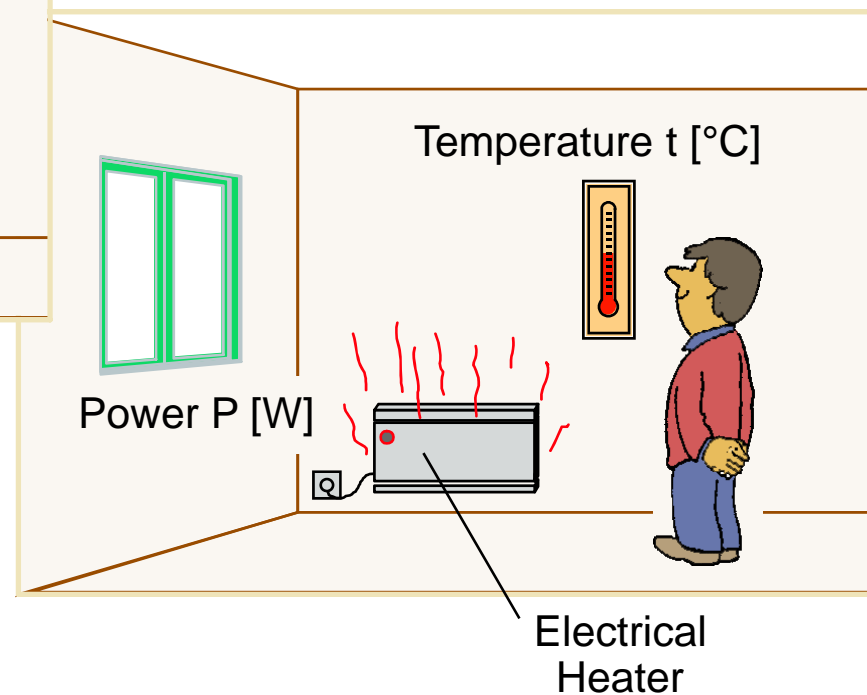
- Units of decibel or dB



Pressure vs. Pressure Level, Power vs. Power Level, and their relationship

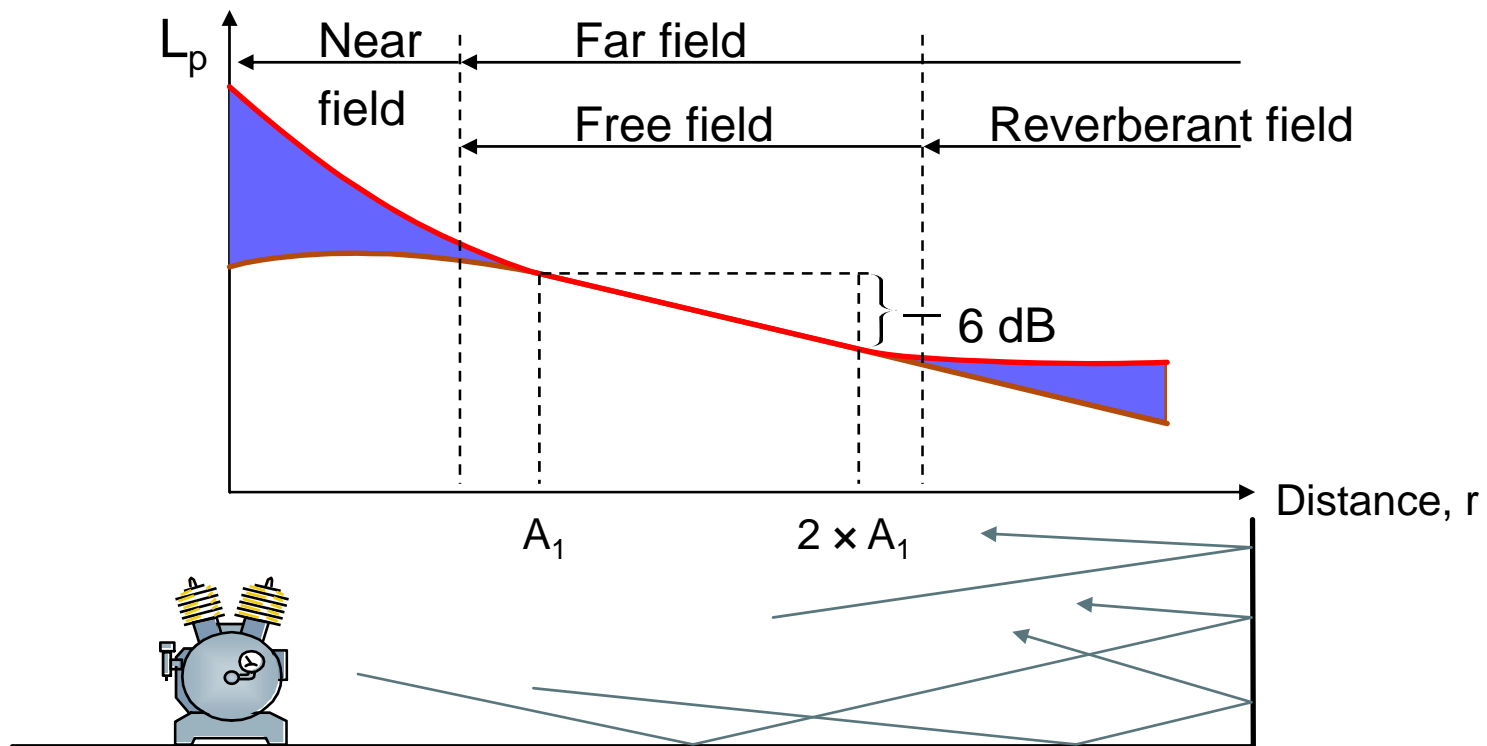


Analogy

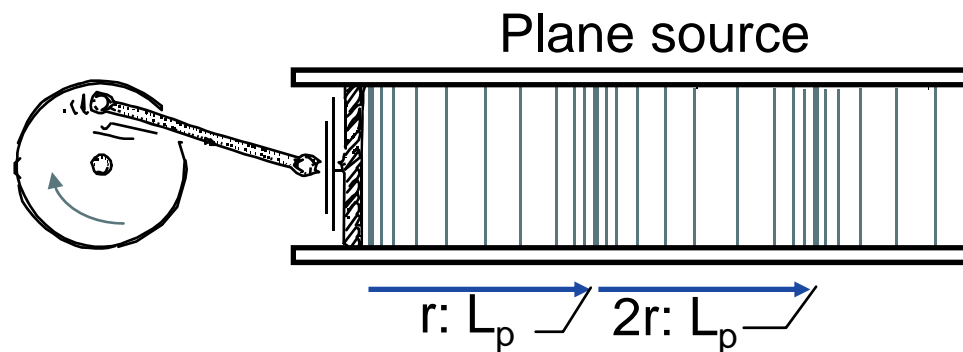
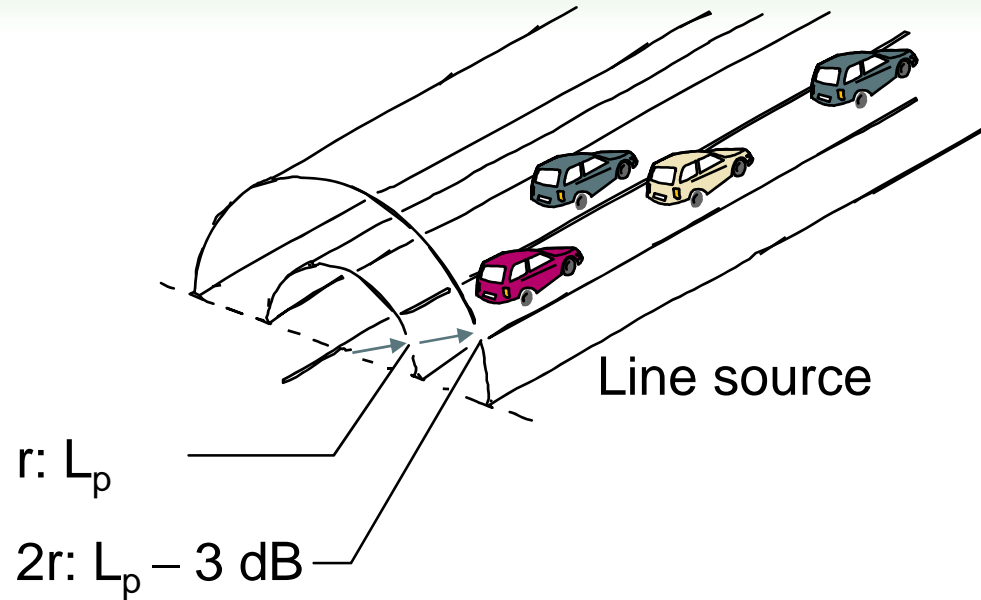
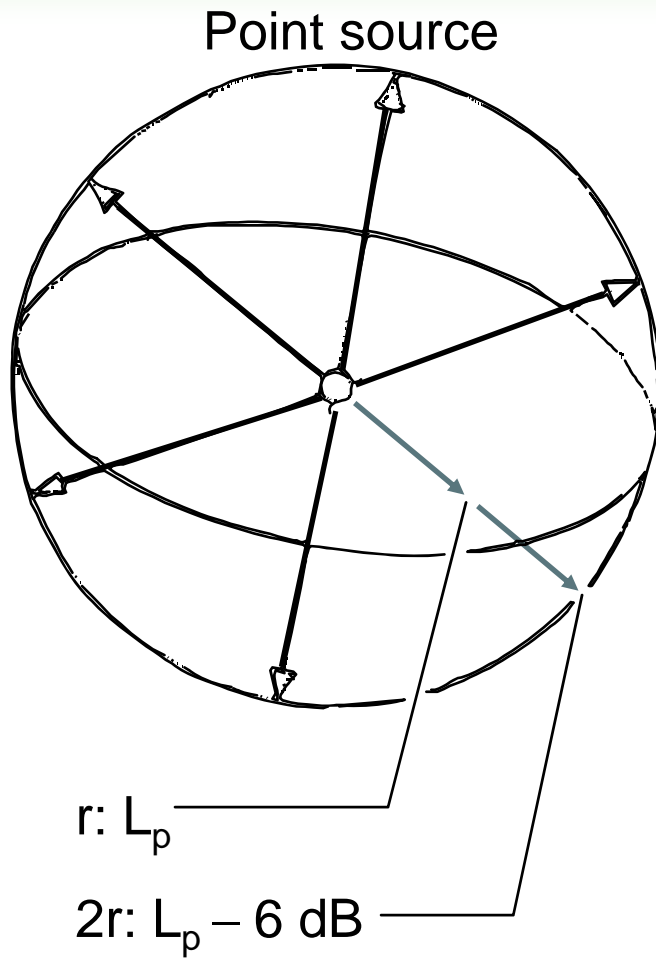


Noise sources and how we characterize them

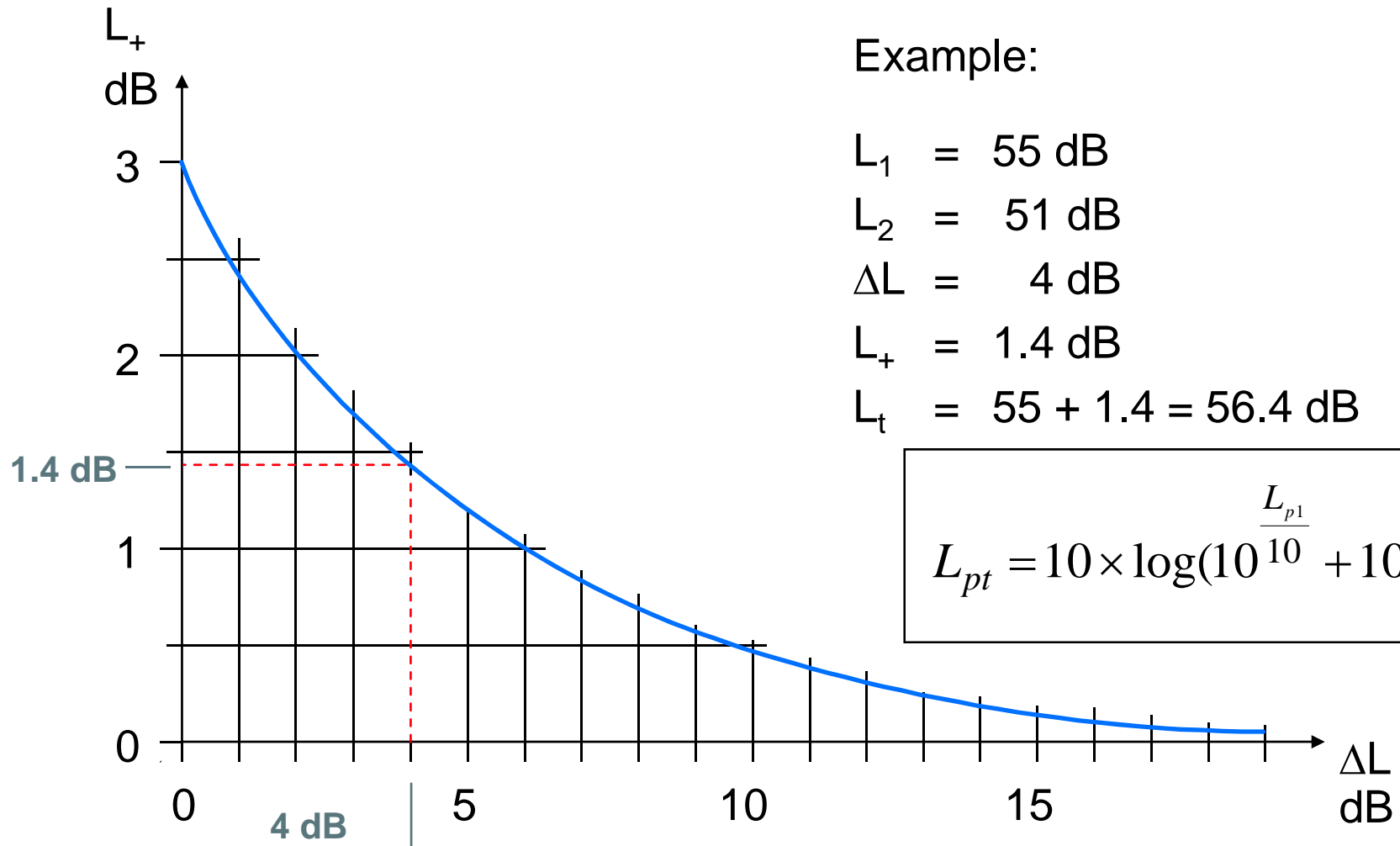
- We need to also understand how the propagation of noise varies with distance. The following shows the acoustic propagation for an ideal point source.
- Measurements should not be conducted in either the near or reverberant field.
- Ideally, we should experience a 6 dB reduction per doubling of distance or 20 dB per decade.



Noise sources and how we characterize them



Adding noise sources



Example:

$$L_1 = 55 \text{ dB}$$

$$L_2 = 51 \text{ dB}$$

$$\Delta L = 4 \text{ dB}$$

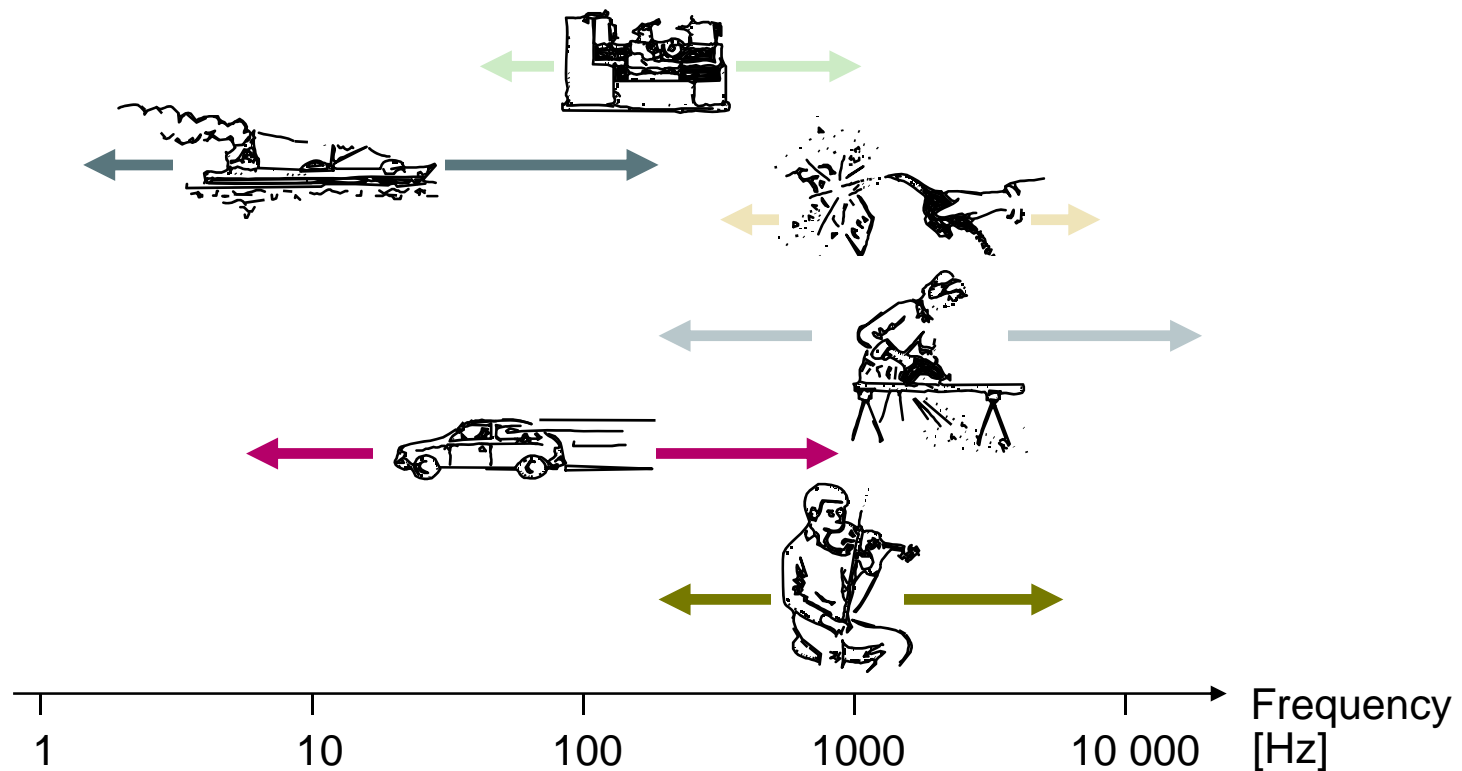
$$L_+ = 1.4 \text{ dB}$$

$$L_t = 55 + 1.4 = 56.4 \text{ dB}$$

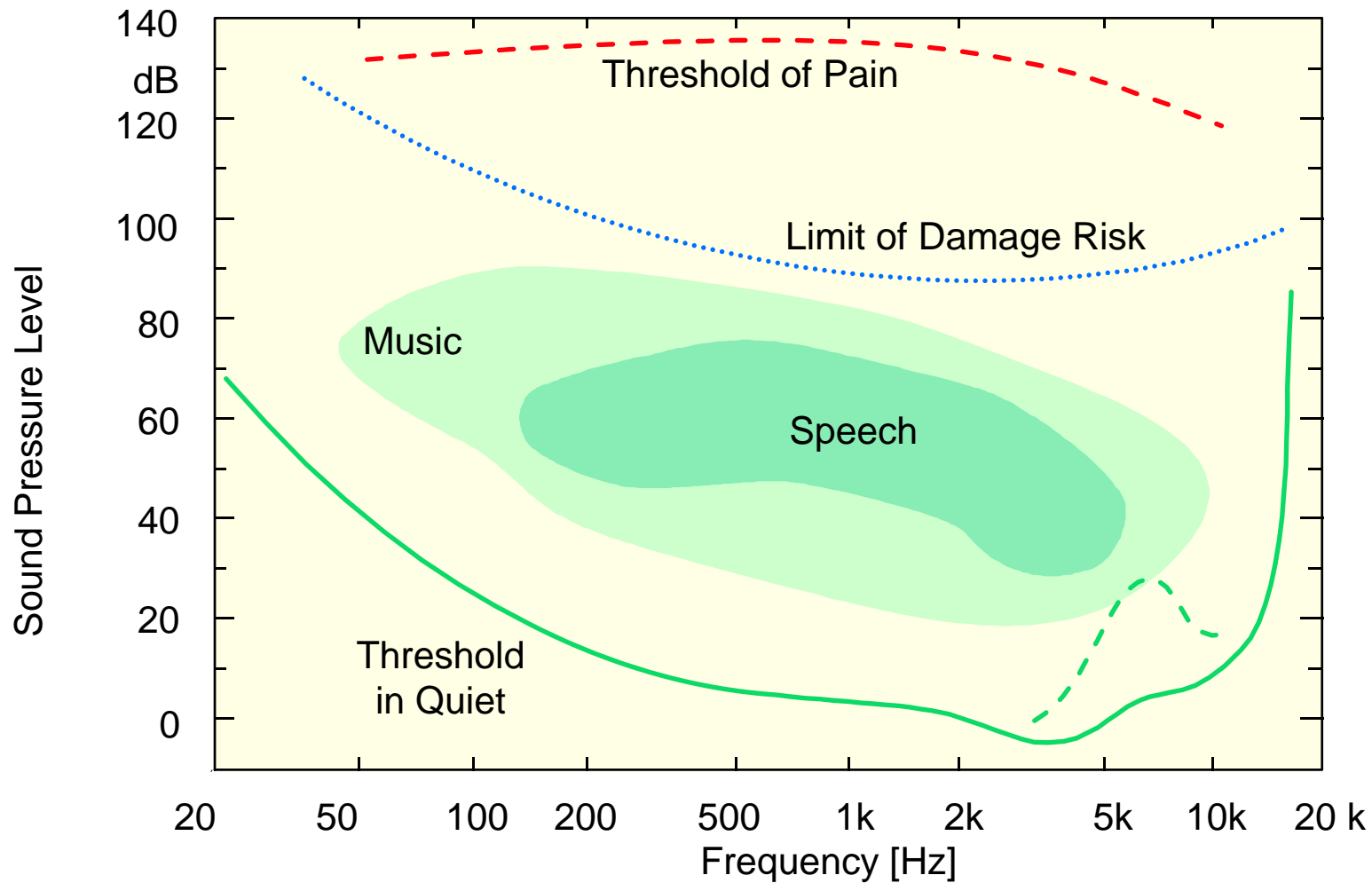
$$L_{pt} = 10 \times \log \left(10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} \right)$$

Frequency and weighting

- Noise sources can be further classified by their frequency characteristics.
- Sources can be pure tones, broadband or narrowband.



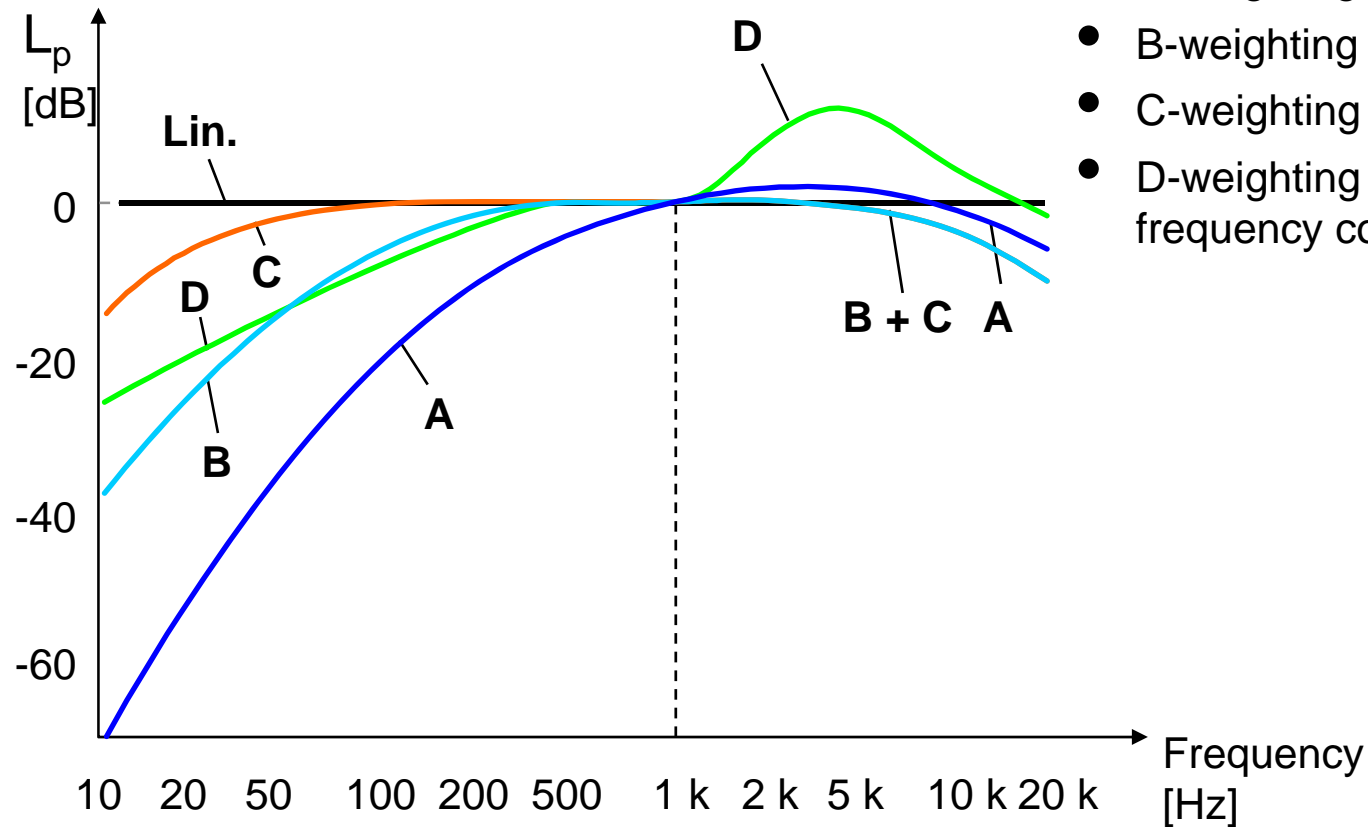
Frequency and weighting



Frequency and weighting

The following weighting curves were designed to be used for noise sources with the following levels:

- A-weighting – 40dB
- B-weighting – 70dB
- C-weighting – 100 dB
- D-weighting – for sources with high frequency content e.g. aircraft



Frequency Analysis Demo

You will hear 5 refrigerator signals, all presented at the same time-averaged A-weighted sound pressure level.

Question: Would you find all of these refrigerator sounds equally desirable in your kitchen?

[Click to Play](#)
[Example](#)

Frequency Analysis Demo

Which refrigerator sound did you like the best?

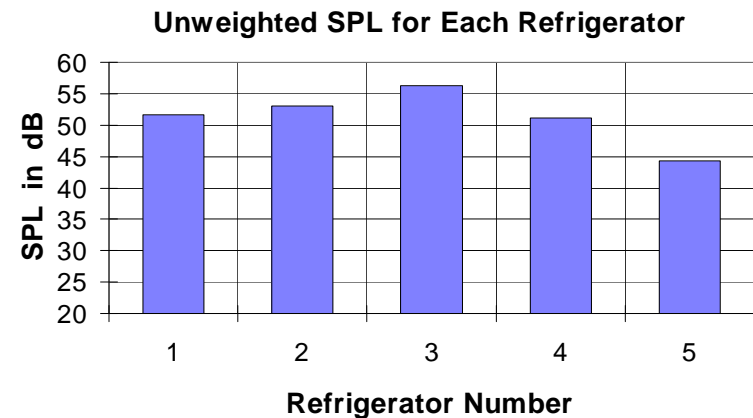
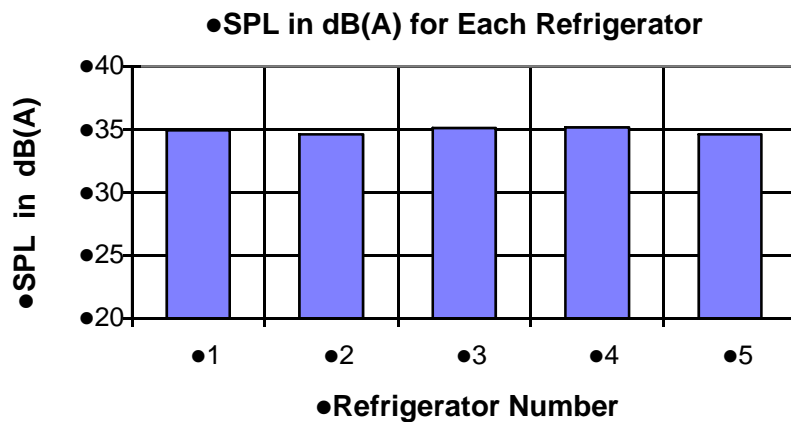
Most people like **refrigerator number 4** the best.

Did you? If not, why not listen again!

[Click to Play
Example](#)

Frequency Analysis Demo

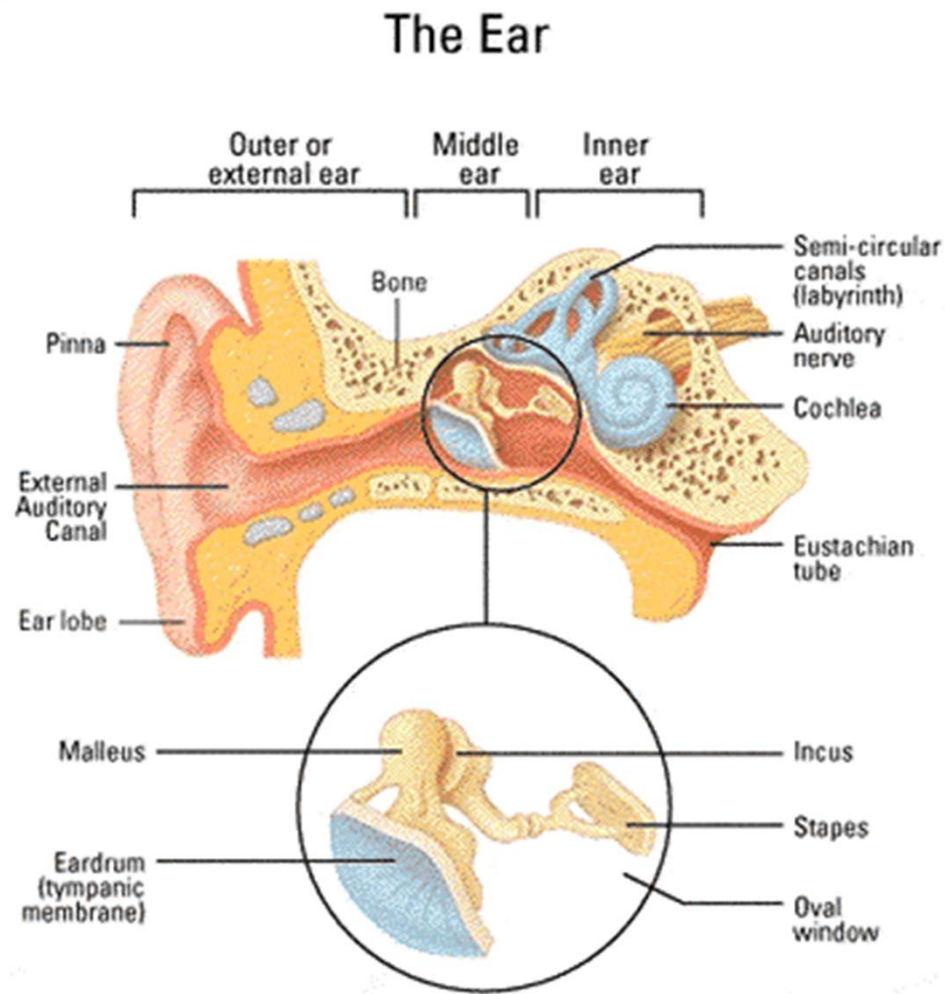
Using traditional SPL measurements for these signals, you can't really see much relationship to your preferences.



Perception of Sound

Change in Sound Level (dB)	Change in Perceived Loudness
1-3	Just perceptible
5	Noticeable difference
10	Twice (or 1/2) as loud
15	Large change
20	Four times (or 1/4) as loud

The Auditory System



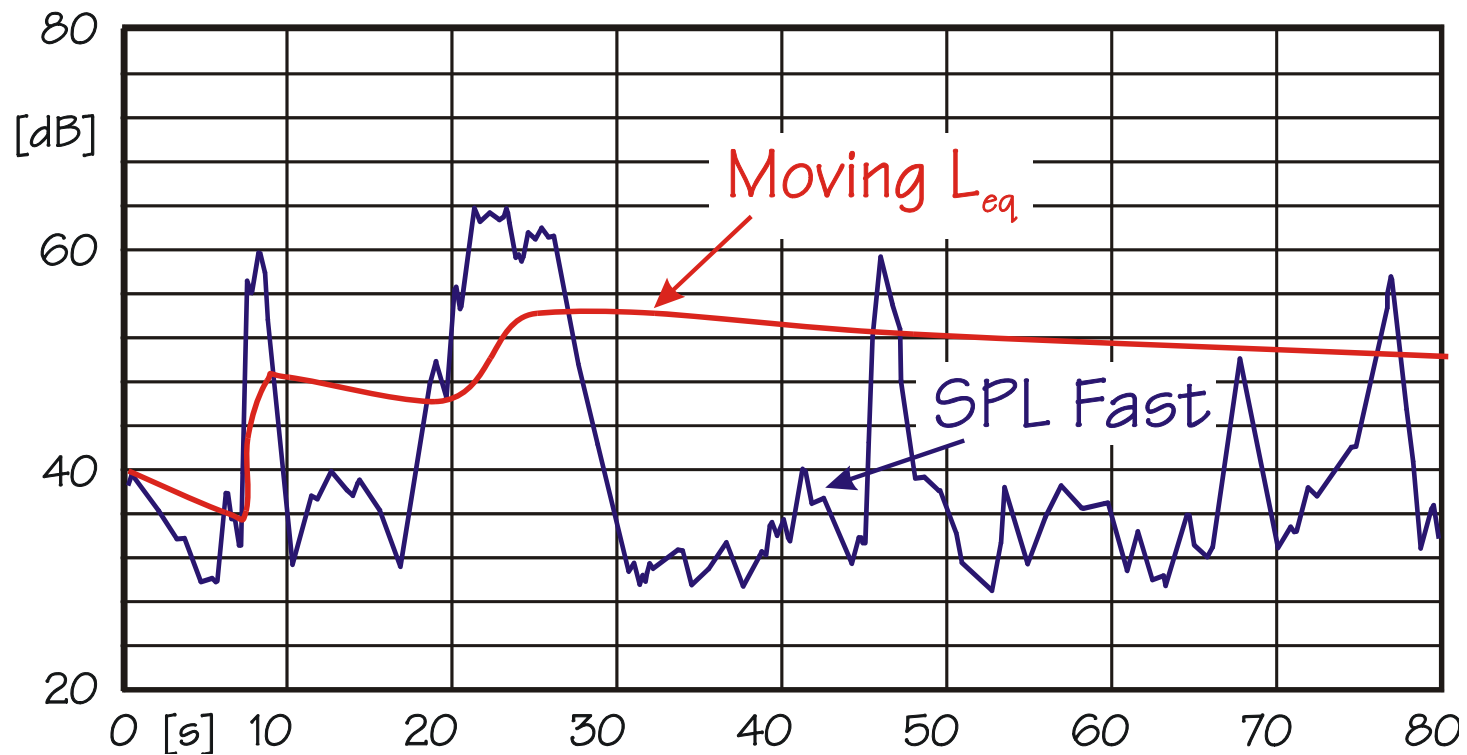
- The ear drum can detect noise by deflecting $1/100$ of a millionth of a cm ($1/10^{\text{th}}$ of a hydrogen molecule diameter)
- Cochlea is a hollow bone about 40 mm long filled with fluid (about the size of a pea)
- It is divided along length by basilar membrane which has 2 240 000 hairs (stereocilia) terminating at 24000 nerve endings

Measuring Community Noise



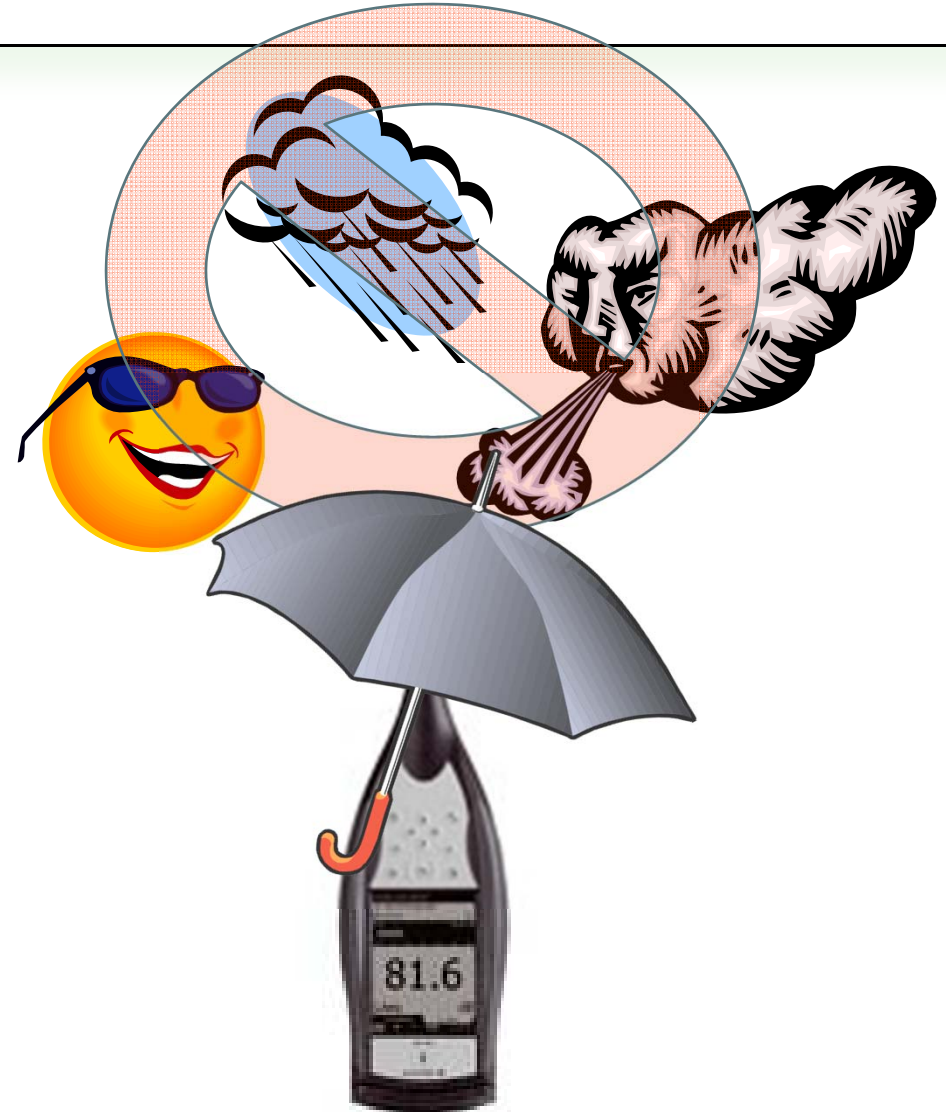
Environmental noise – equivalent sound level (L_{eq})

- L_{eq} is a parameter which calculates a constant level of noise with the same acoustic energy content as the time varying noise signal being measured.
- In other words, the L_{eq} is an energy mean of the noise level averaged over the measurement period.



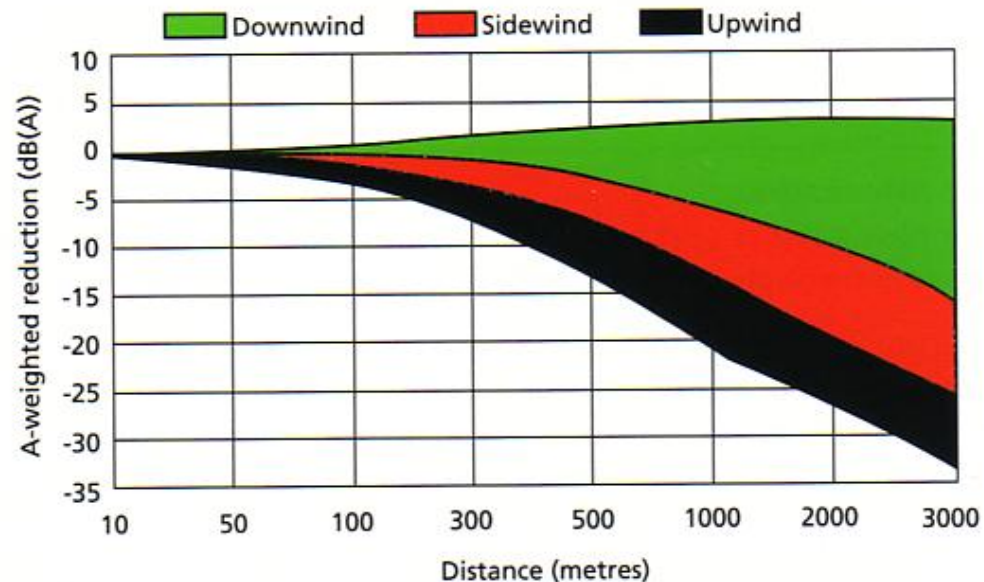
Weather considerations

- For environmental noise measurements it is important that procedure for weather conditions be adhered to.
- Many agencies specify acceptable metrological conditions for validity of acquired data.
- Parameters include: wind, temperature, precipitation, humidity, etc.



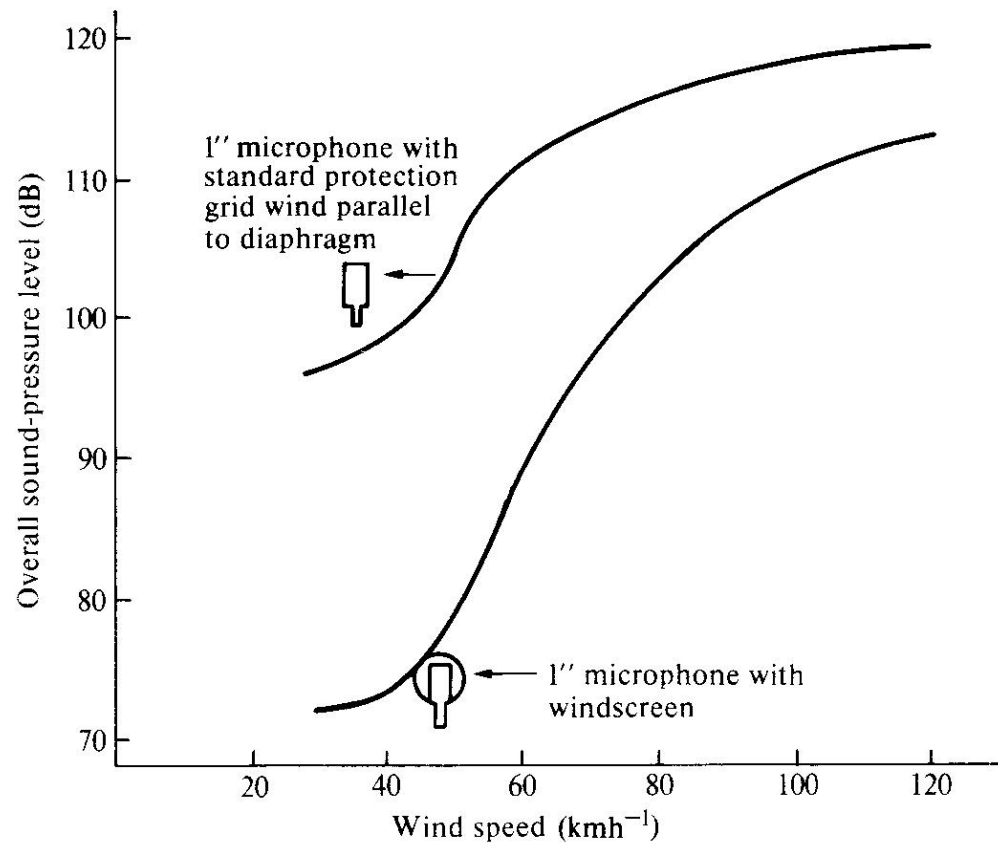
Weather considerations

- Wind has little influence on the measured sound level for distances up to 50 metres from the source.
- Whenever possible environmental noise measurements of a source should be conducted down-wind so as to avoid an apparent acoustic “shadow” which can occur on the up-wind or side-wind direction of the source.
- It is also good practice to avoid environmental noise measurements where wind gusts exceed 10 mph or 15 km/h.



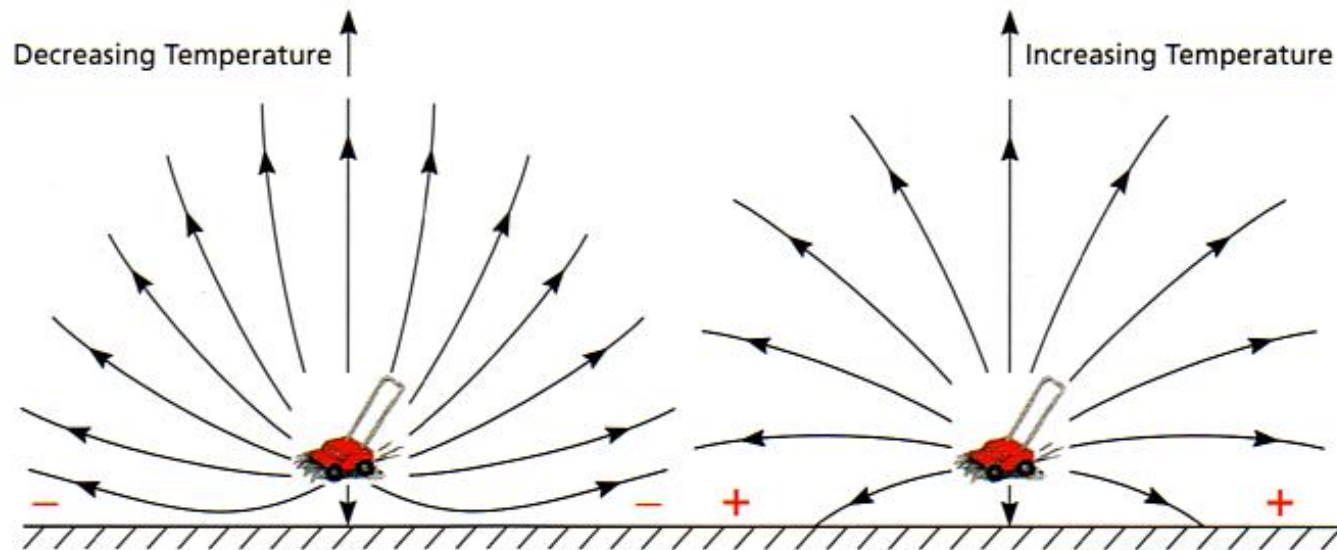
Weather considerations

- Shown below is the effect of wind noise on a microphone with and without a wind screen as a function of the wind speed.



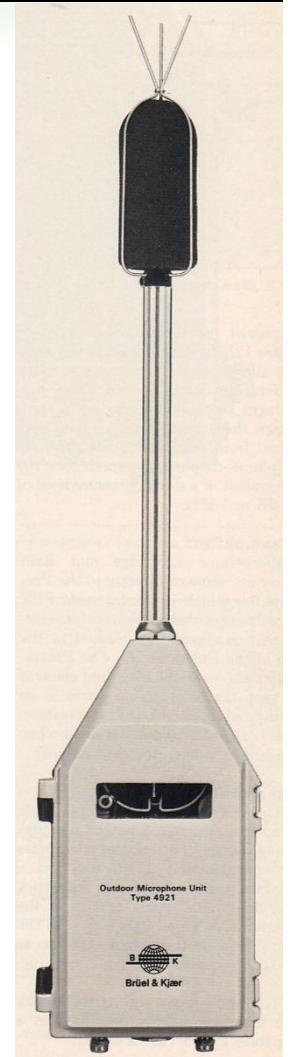
Weather considerations

- On a clear sunny day the temperature can have the effect of decreasing with altitude giving a shadow effect for sound.
- On a clear night a temperature inversion will have an effect of focusing the sound on the ground.



Weather considerations

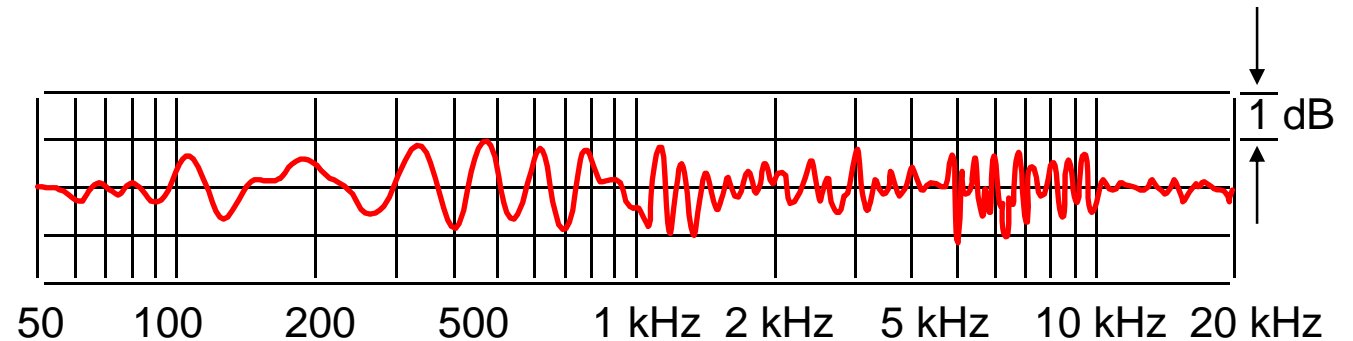
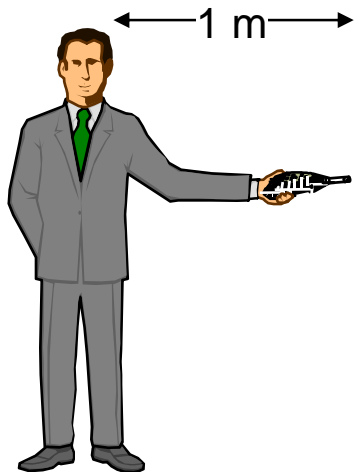
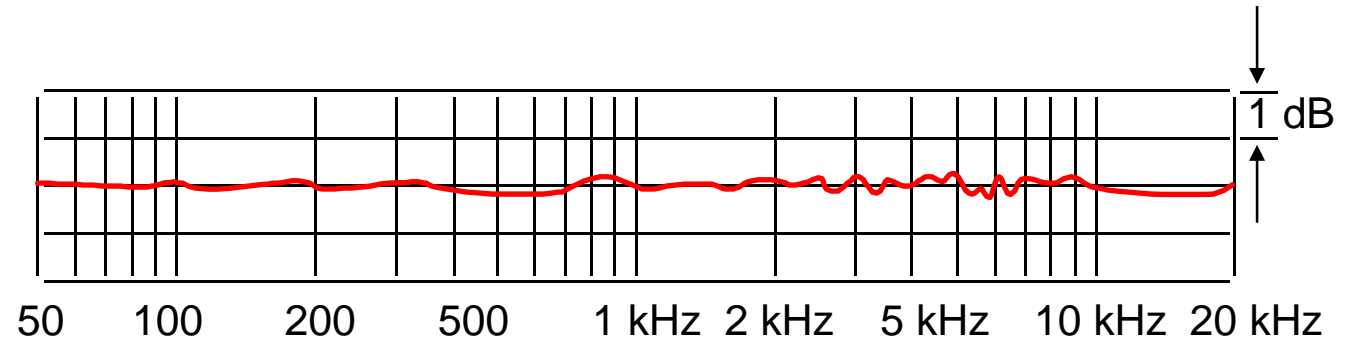
- It is good practice to avoid environmental noise monitoring during periods of precipitation.
- Humidity greater than 90% can affect the response of the environmental noise monitoring microphone.
- Long-term monitoring stations should be water tight, dry/warm with a wind screen and bird spike.



Influence of the Environment



Influence from Sound Level Meter and Operator



Accuracies for Sound Level Meters

Four levels of accuracy for Sound Level Meters

- Type 0: Laboratory Standard
- Type 1: Precision (Field and Laboratory)
- Type 2: General Purpose (Field)
- Type 3: Survey (Field)



Acoustic Calibration

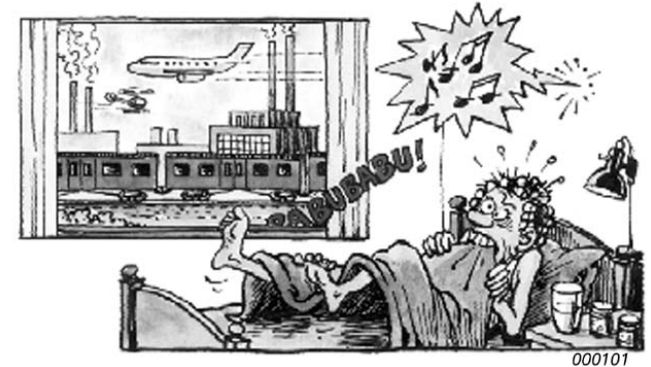


- You should calibrate your sound level meter before and after each measurement
 - ⌘ Indication that your equipment is working correctly
 - ⌘ Regulatory requirements (law suit)
- Ensure that your calibrator has been annually factory certified with a valid calibration
- Permanent monitors are calibrated and inspected annually

Sources and receptors

- Sources of environmental noise include:

- Industrial facilities
- Road traffic noise
- Rail traffic noise
- Aircraft noise



- Receptors are classified as places of residence and relaxation:

- Houses, apartments, condominiums
- Hospitals
- Schools
- Cottages and resorts

- Consideration must be given to what receivers are considered for noise impact from a given source. This is usually dictated through legislation (often 3 to 500 metres from a source).

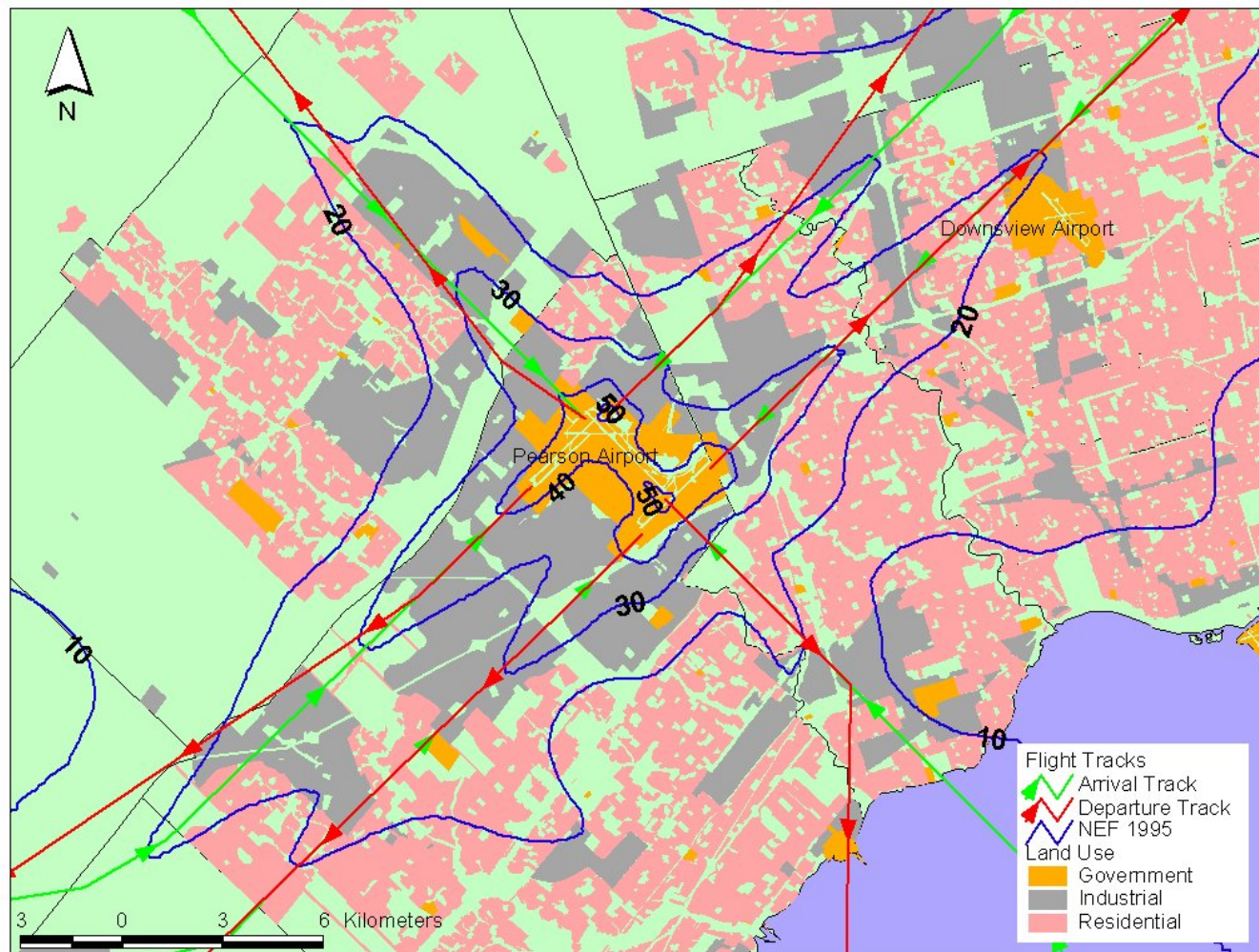
Sources and receptors

Aircraft Noise

- Aircraft noise is best controlled through appropriate planning, zoning and land use as well as through aircraft movement management.
- It is imperative that airport noise be continuously monitored.
 - Some permanent monitoring stations communicate with controlling radar to identify particularly noisy aircraft for future control.
- Aircraft environmental noise is modelled and mapped to establish contours (in Canada referred to as NEF contours) for use in residential planning.
- For development in affected areas, houses can be protected with upgraded windows and roofs for additional sound abatement.



NEF Contours



Permanent Noise Monitoring Terminals (NMT)



Understanding Environmental Capacity

First Law

$$E = T - I$$

Where E = Environmental Capacity

T = Community
tolerance

I = Environmental
impact

Impact reduction

Equipment improvements
New operating practices
Limit operating times
Noise Barriers

Tolerance Building

Web portals
Community forum
Education
Visitors centres

Proactive, Balanced Approach

Second Law

$$T = X - P$$

Where T = Tolerance

X = eXpectation

P = Perception

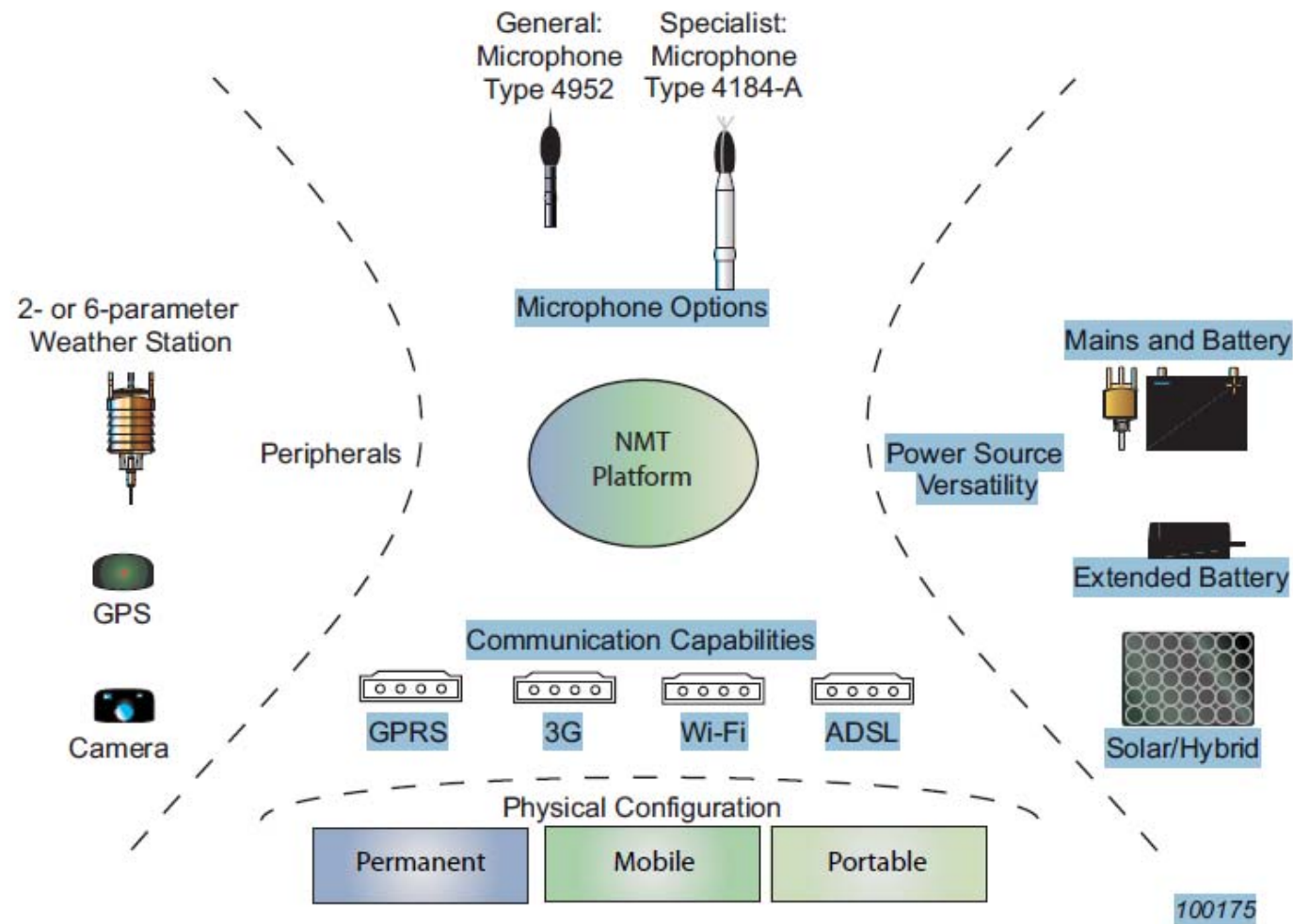
*Managing expectations and perceptions is
critical*

3639-A Permanent/Mobile NMT



- Includes Type 2250 Sound Level Meter
- Type approved to IEC 61672 Class 1 specifications; uniquely, including windscreen effects
- 120 dB dynamic range
- On-board memory and auto-resend for avoiding holes in data
- LAN, WLAN, 3G, GPRS and CDMA communications capabilities for remote operation
- Wide range of integrated peripherals for communications, powering, mounting, weather, GPS, camera, etc

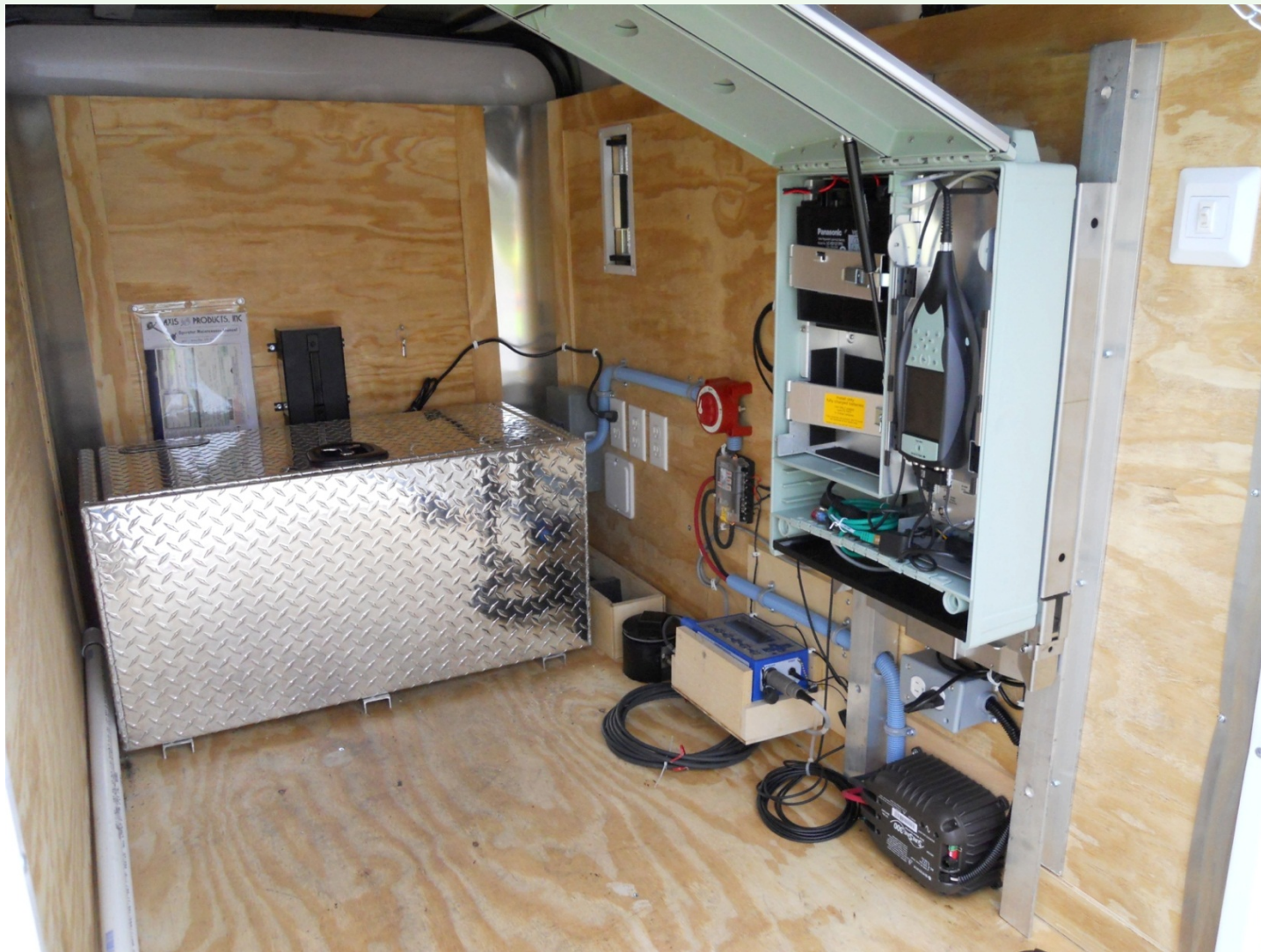
NMT Hardware Options



3639-A Mobile NMT



3639-A Mobile NMT



3639-A Mobile NMT



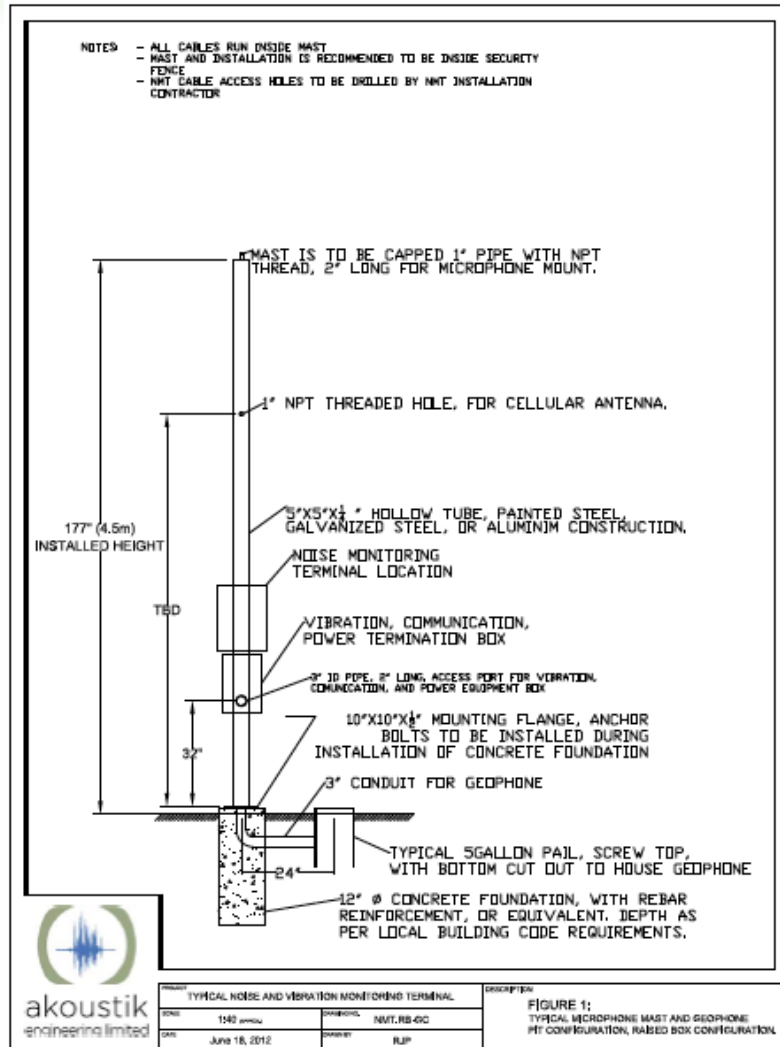
3655-C Portable NMT



GTAA Installation



Typical NMT Mast Design



DONE!