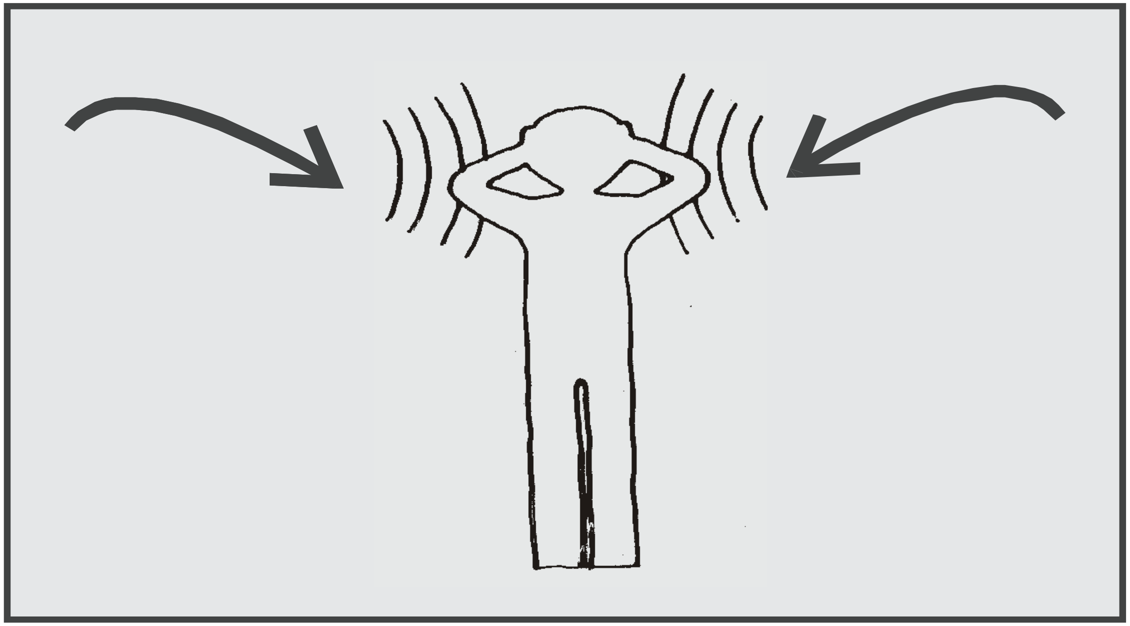
Lesson Two

Basic Acoustic and Traffic Noise Concepts

This lesson presents information on:

- Basic concepts of sound and noise
  - Frequency
  - Time
  - Magnitude
- Decibels
  - A-weighting
  - Adding decibels
- Noise level descriptors
- Sound propagation
- Shielding
- Noise barrier placement

Noise is unwanted sound

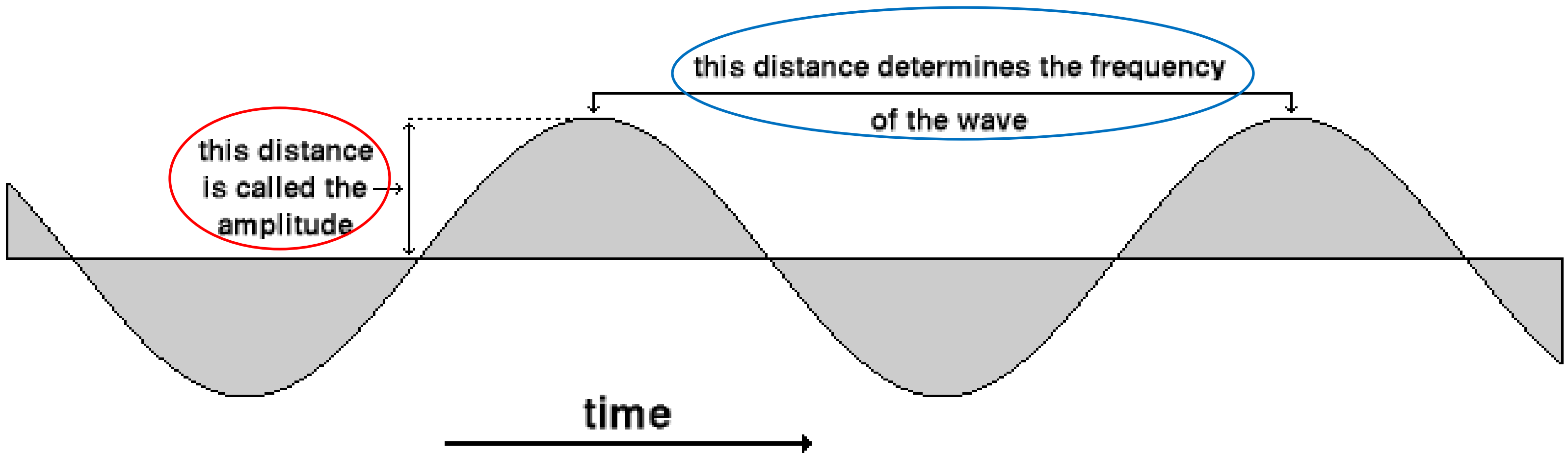


What is sound?

Sound is the sensation produced by stimulation of the organs of hearing by vibrations transmitted through the air or other medium. (From: www.dictionary.com)

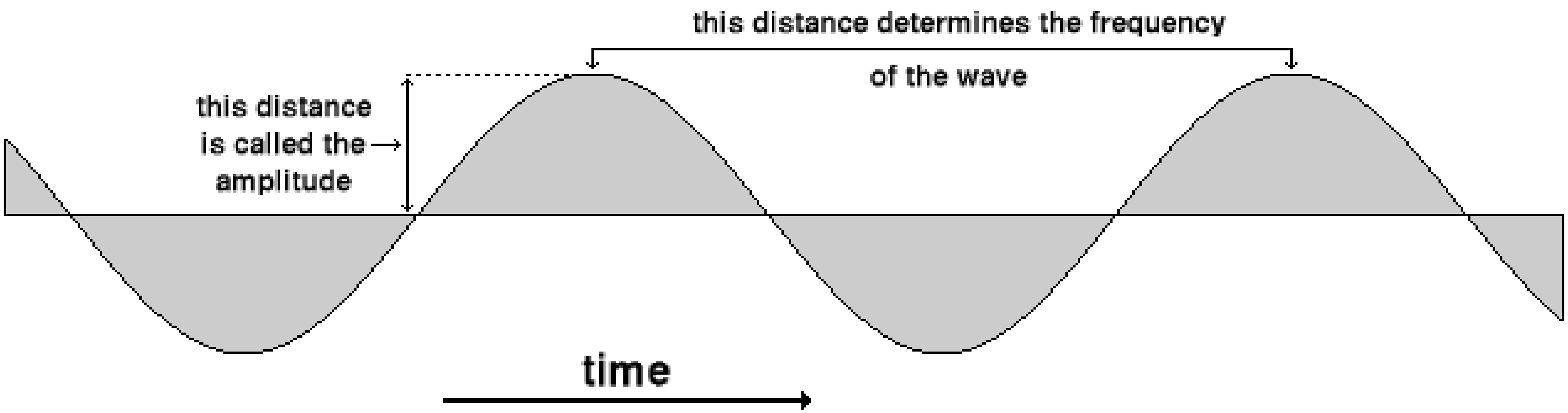
3 Basic Dimensions of Sound:

- **Magnitude/Amplitude (the "loudness")**
- Frequency (the "pitch")
- Time (both duration and variation)



Frequency is the number of cyclical crests\variations (wavelengths) per unit of time. Frequency is generally expressed in cycles per second, also denoted as Hertz (Hz).

Source: Noise Control Reference Handbook, 1989



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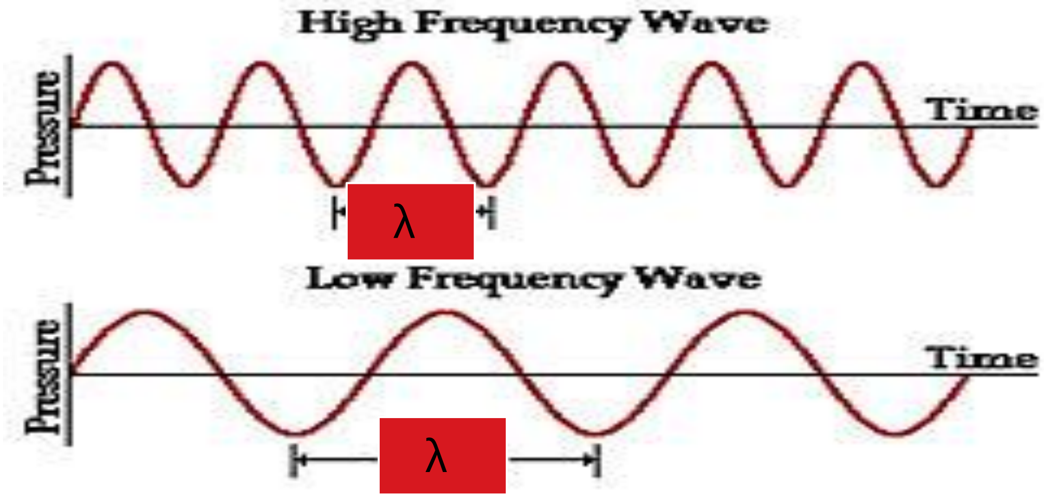
Wavelength (λ) is the distance, measured in the direction of propagation, between two points of the same phase in consecutive cycles of a wave.

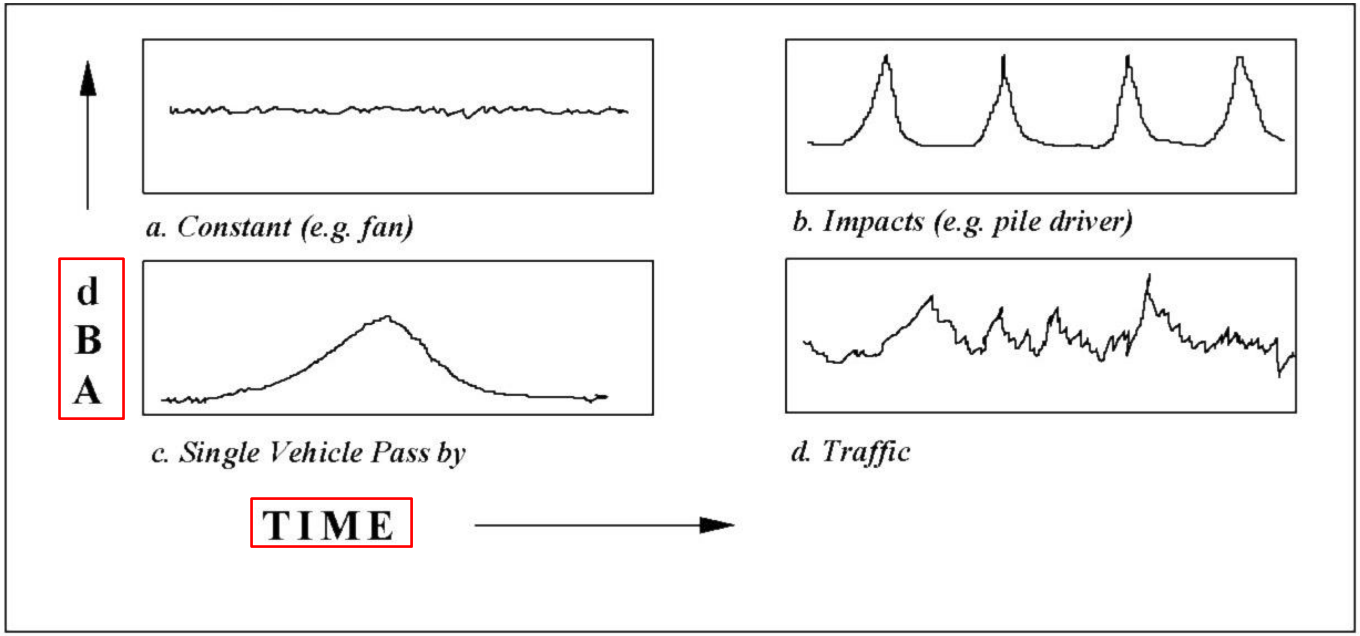
Source: www.dictionary.com



Source: www.physicsclassroom.com

Noise is described based on its sound intensity over a given period of time.

This is illustrated here:



Source: CALTRANS Technical Noise Supplement, 1998

Magnitude is what can be measured – the "loudness"

Sound/Acoustic Power – The sound energy emitted per unit of time.

Sound Pressure – The sound measured at a point in space (x) distance from the source to a "receptor".

Sound Power is the source – Sound Pressure is the effect

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- *Sound pressure is measured in sound pressure level (no units) – named bels
- Log of the square of the ratio of pressures
- Since a decibel is one tenth of a bel our equation is as follows in decibels (dB(A)):

$$\text{Sound Pressure Level (SPL)} = 10\ \text{Log}_{10}\left(\frac{P_1}{P_0}\right)^2 \text{dB}$$ *

Where:

P_1 is a sound pressure

P_0 is a reference pressure, standardized as 20 μPa ◊

Source: CALTRANS Technical Noise Supplement (TENS), 1998

◊ Threshold of hearing

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Sound is measured in decibels with a sound level meter (dosimeter)

- **To give you an idea of what the standardized sound pressure is:**
- **1 Pa = 1 N/m^2 = 1kg•m/sec^2 =.00014504 lbs/in^2**
- **1 μPa = 1 X 10^{-6} Pa**
- **20 μPa = 20 X 10^{-6} Pa**
- ***20 μPa = .00002653 lbs/in^2**

***Threshold of hearing - roughly the sound of a mosquito flying 3 m (10 ft) away**

- Sound pressure levels are expressed in terms of the reference sound pressure in <u>bels</u> (Alexander Graham Bell) by the following formula:
- Sound Pressure Level (SPL)= $\log_{10}\left(\frac{P_1}{P_0}\right)^2$ bels

Sound Level Meters – designed to give readings of sound pressure levels.

Sound Level Meters offer a selection of frequency weighting networks designated as A, B, C, D and Z.

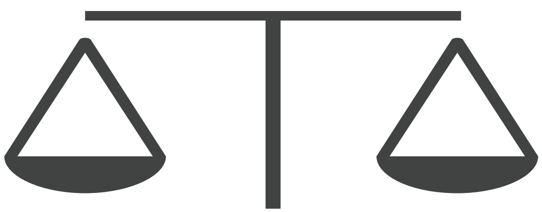
The human ear is much more sensitive to midrange frequencies between 1,000 Hz and 6,300 Hz (although human hearing covers the frequency range of 20 Hz to 20,000 Hz) – less sensitive to very low or very high pitch sounds.

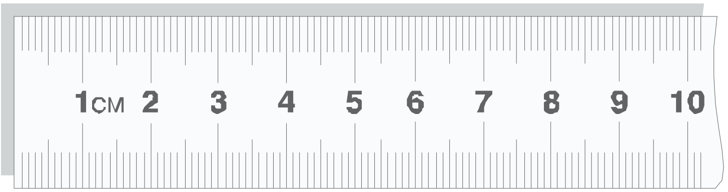
Depending on the weighting network, the meter calculates the measurements to ensure it is measuring what you actually hear.

A decibel is a unit of sound pressure level which denotes the ratio between two quantities that are proportional to power.

A Decibel is……***Not an Amount like:***

A WEIGHT **OR** **A DISTANCE**





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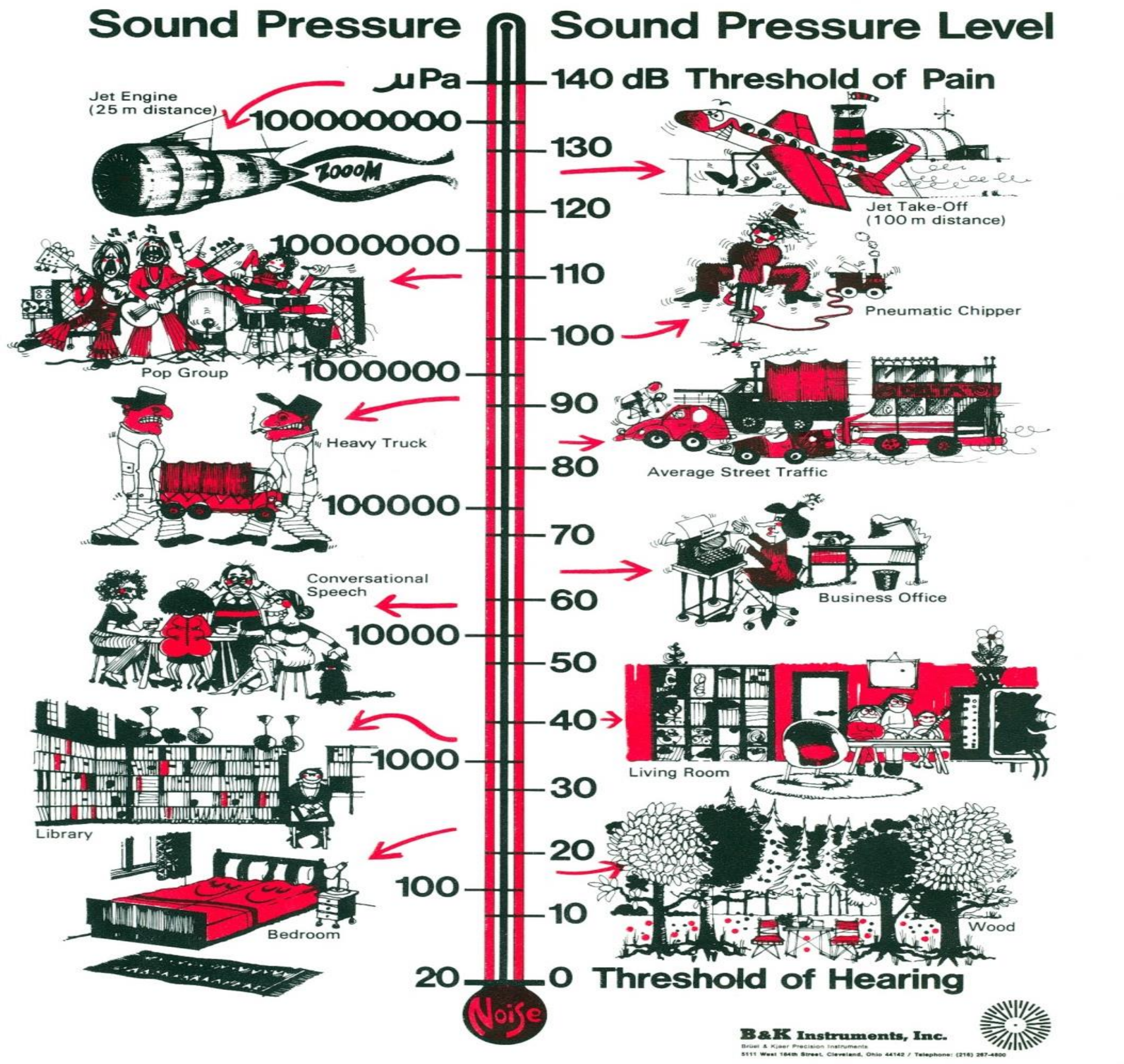
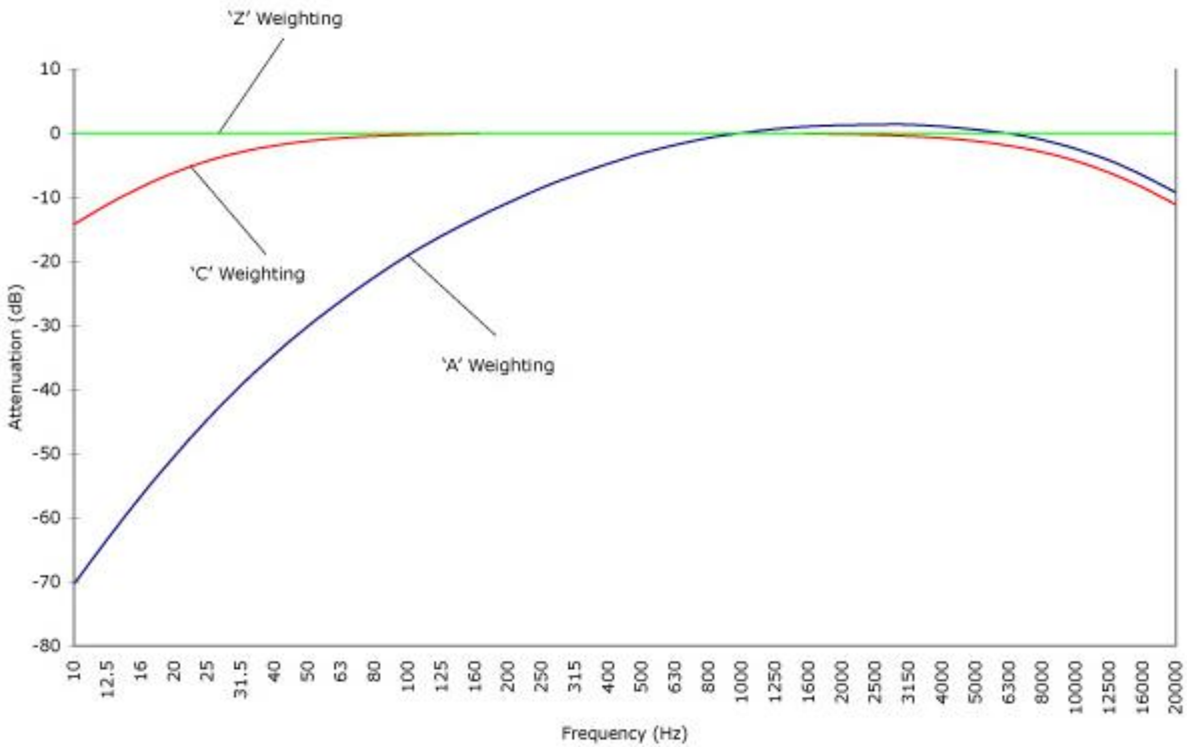


A-weighting is the frequency weighting network used to account for changes in sensitivity as a function of frequency. This weighting network most closely approximates the way the human ear perceives sound.

Comparison of A, C, and Z Weighting



The meter adjusts Sound Pressure Levels (SPLs) up or down based on the frequency (and weighting filter).

Comparison of Decibel Changes, Loudness, and Energy Loss

Sound Level Change	Relative Loudness	Acoustic Energy Loss
0 dB(A)	Reference	0
+/-3 dB(A)	Barely Perceptible Change	50%
+/-5 dB(A)	Readily Perceptible Change	67%
+/-10 dB(A)	Half as Loud	90%
+/-20 dB(A)	1/4 as Loud	99%
+/-30 dB(A)	1/8 as Loud	99.9%

Source: Highway Traffic Noise: Analysis and Abatement Guidance (FHWA, 2010)

How are decibels added?

(Because 50 dB(A) + 50 dB(A) DOES NOT = 100 dB(A))

When two decibel values differ by:	Add the following to the HIGHER value:	Example
0 or 1 dB(A)	3 dB(A)	70 dB(A) + 69 dB(A) = 73 dB(A)
2 or 3 dB(A)	2 dB(A)	74 dB(A) + 71 dB(A) = 76 dB(A)
4 to 9 dB(A)	1 dB(A)	66 dB(A) + 60 dB(A) = 67 dB(A)
10 dB(A) or more	0 dB(A)	65 dB(A) + 54 dB(A) = 65 dB(A)

Now let's try adding the following decibel levels together:

75 dB(A)
68 dB(A)
88 dB(A)
82 dB(A)
79 dB(A)
?? dB(A) Total

The first step is to put the decibels in order from lowest to highest as shown here:

68 dB(A)
75 dB(A)
79 dB(A)
82 dB(A)
88 dB(A)
?? dB(A) Total

Next, begin adding the values in pairs, beginning with the smallest two levels:

68 dB(A)
75 dB(A) = 76 dB(A) = 81 dB(A) = 85 dB(A) **= 90 dB(A)**
79 dB(A)
82 dB(A)
88 dB(A)
?? dB(A) Total

When two decibel values differ by:	Add the following to the HIGHER value:
0 or 1 dB(A)	3 dB(A)
2 or 3 dB(A)	2 dB(A)
4 to 9 dB(A)	1 dB(A)
10 dB(A) or more	0 dB(A)

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66 dB(A) ← 1 car
66 dB(A) ← +1 car
69 dB(A)
66 dB(A) ← +1 car
71 dB(A)
66 dB(A) ← +1 car
72 dB(A)
66 dB(A) ← +1 car
73 dB(A)
66 dB(A) ← +1 car
74 dB(A)
66 dB(A) ← +1 car
75 dB(A)
66 dB(A) ← +1 car
76 dB(A)

How many cars at 66 dB(A) does it take to have a perceived doubling of sound?

When two decibel values differ by:	Add the following to the HIGHER value:
0 or 1 dB(A)	3 dB(A)
2 or 3 dB(A)	2 dB(A)
4 to 9 dB(A)	1 dB(A)
10 dB(A) or more	0 dB(A)

Remember: An increase or decrease of 10 dB(A) is perceived as a doubling or halving of sound.

76 dB(A) – 66dB(A) = 10 dB(A) increase

ANSWER = 8 cars total

Sound Level Descriptors

- Descriptors are the various metrics (can also be called "measures") used to describe noise under various conditions.

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NOISE DESCRIPTOR	DEFINITION
L_{MAX} (Maximum Noise Level)	The highest instantaneous noise level during a specified time period. The use of "peak" level should be discouraged because it may be interpreted as a non-r.m.s. noise signal.
L_X (A Statistical Descriptor)	The noise level exceeded X percent of a specified time period. The value of X is commonly 10. Other values of 50 and 90 are sometimes also used. *Examples:* L_{10}, L_{50}, L_{90}
L_{eq} (Equivalent Noise Level. Routinely used by FDOT and FHWA to address the worst noise hour) (L_{eq}(h))	The equivalent steady state noise level in a stated period of time that would contain the same acoustic energy as the time varying noise level during the same period.

Source: CALTRANS Technical Noise Supplement, 1998

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NOISE DESCRIPTOR	DEFINITION
L_{dn} (Day - Night Noise Level. Used commonly for describing community noise levels).	A 24-hour L_{eq} with a "penalty" of 10 dBA added during the night hours (2200 - 0700). The penalty is added because this time is normally sleeping time.
CNEL (Community Noise Equivalent Level. A common community noise descriptor, also used for airport noise).	Same as the L_{dn} with an additional penalty of 4.77 dBA, (or 10 Log 3), for the hours 1900 to 2200, usually reserved for relaxation, TV, reading and conversation.
SEL (Single Event Level. Used mainly for aircraft noise, it enables comparing noise created by a loud, but fast overflight, with that of a quieter, but slow overflight).	The acoustical energy during a single noise event, such as an aircraft overflight, compressed into a period of one second, expressed in decibels.

Source: CALTRANS Technical Noise Supplement, 1998

So Which Descriptor Does the FDOT Use?

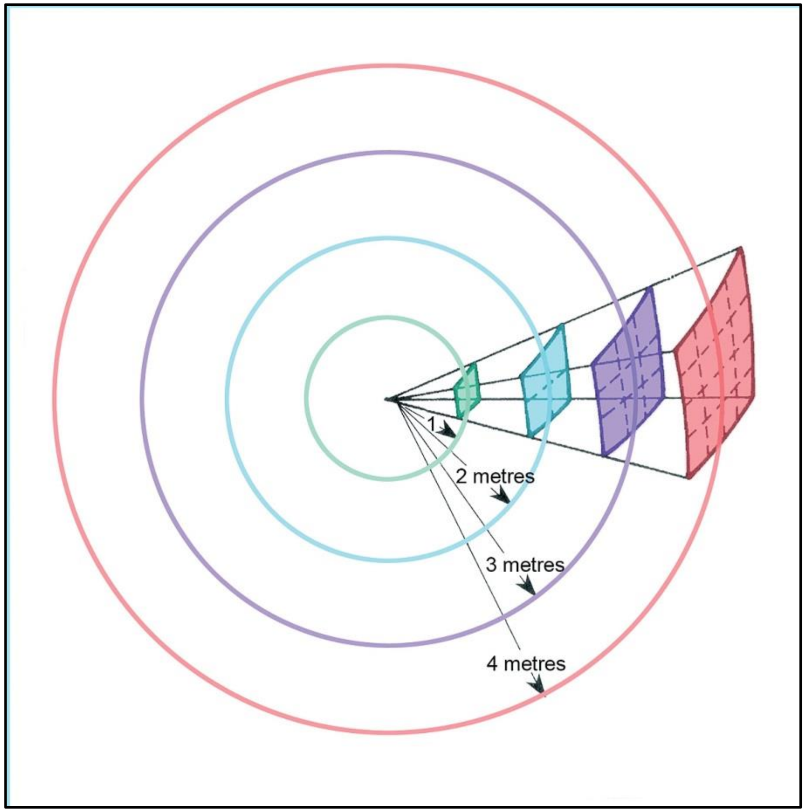
FDOT uses the descriptor Leq(h) to describe highway traffic noise.

What is sound propagation?

- The manner in which sound travels through a compressed medium (such as air)

➢ Propagation is Influenced By…..

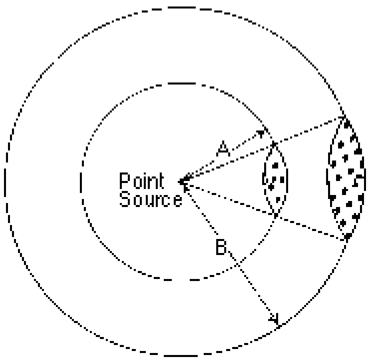
- *Geometric spreading* from point and line sources
- Ground Effects
- Atmospheric Effects
- Shielding (by both natural and man-made features)

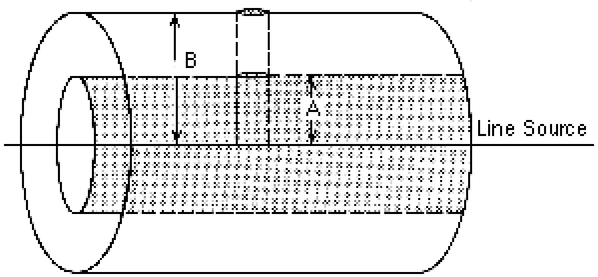


Source: www.performing-musician.com

Geometric Spreading – 2 Primary Types:

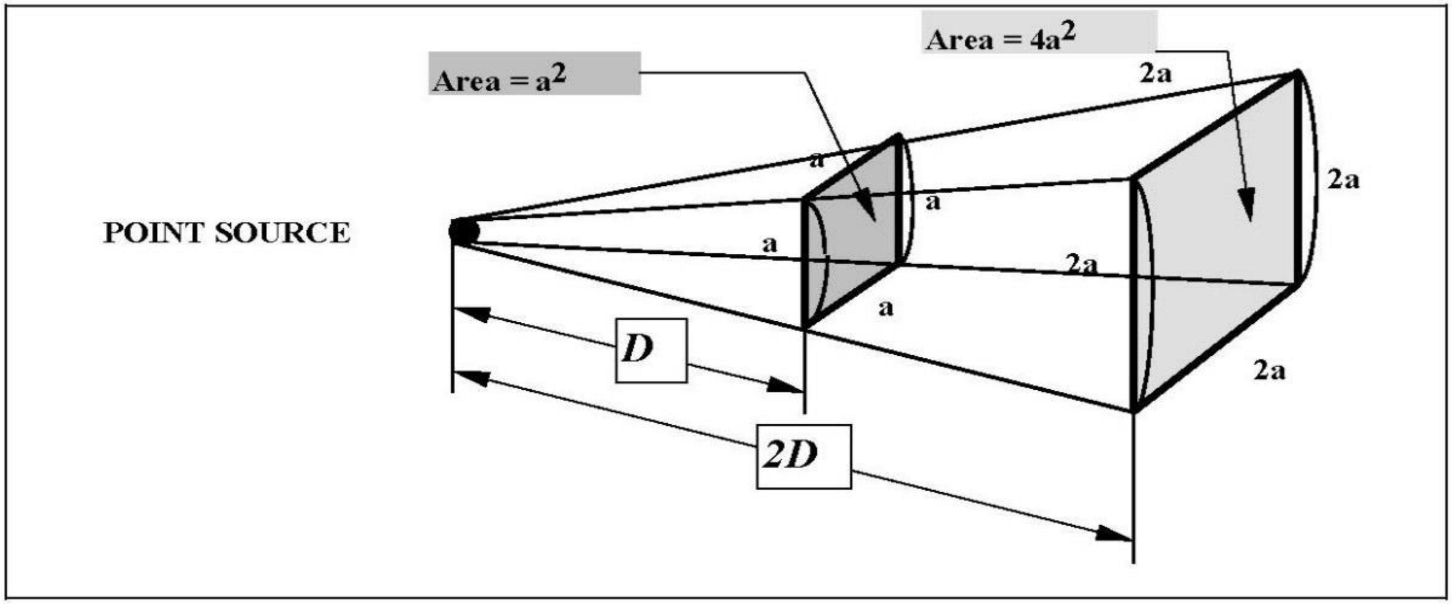
- Spherical Spreading (From a point source)
  - Like pile driving
- Cylindrical Spreading (From a line source)
  - Like traffic





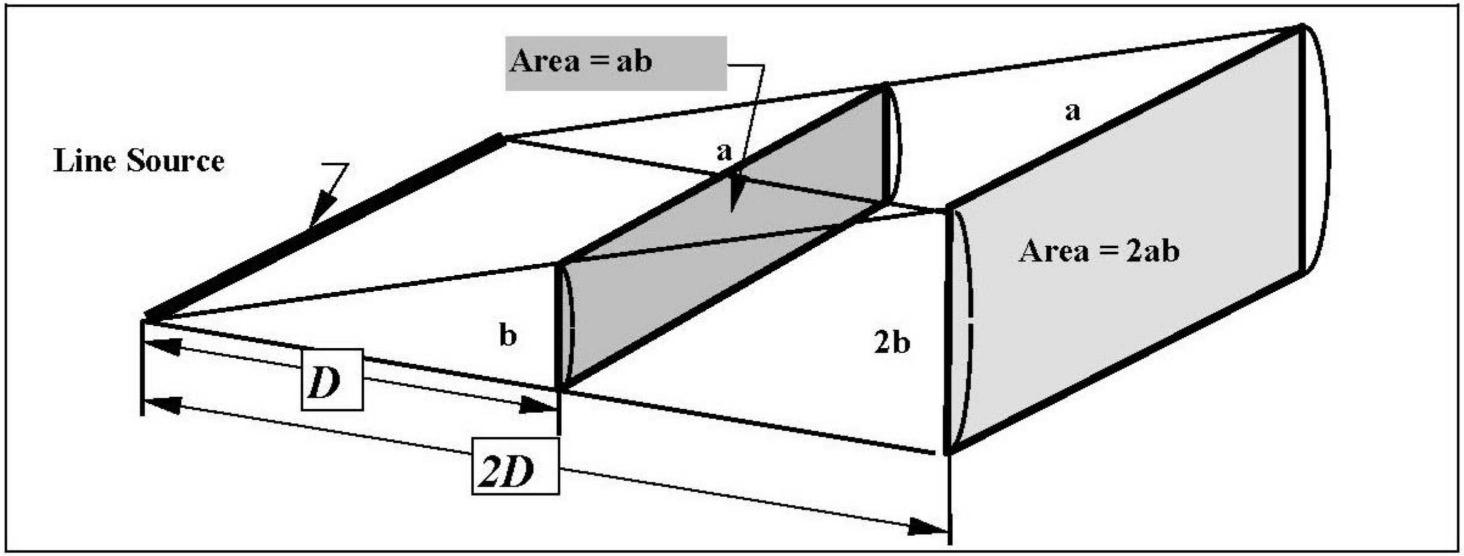
Source: Handbook for Acoustic Ecology
https://www.sfu.ca/sonic-studio-webdav/handbook/Sound_Propagation.html

A point source radiates outward uniformly from the source in a spherical pattern. The sound level attenuates (decreases) at a rate of 6 dB(A) for each doubling of the distance from the source.



Source: CALTRANS Technical Noise Supplement, 1998

A line source (such as highway traffic) makes the sound appear to emanate from a line rather than a point, which results in cylindrical spreading. The sound level attenuates at a drop-off rate of 3 dB(A) for each doubling of distance.



Source: CALTRANS Technical Noise Supplement, 1998

Receptors vs. Receivers

RECEPTOR

- A discrete or <u>representative</u> location of a noise sensitive area(s), for any of the land uses listed in FHWA's NAC Table
- A specific XY point in the Traffic Noise Model for which traffic noise is *predicted* for

RECEIVER

- A physical real-life recipient of noise
- A human or animal ear

Oftentimes, these two words are used interchangeably. Some instances require the use of one word or the other.

Ground absorption is how the ground surface tends to absorb or reflect traffic noise. There are two general classifications for the ground surface type:

- Hard Sites
- Soft Sites

A "Hard Site" is a reflective ground surface between the source and the receptor, such as:

- Parking Lots (Concrete, asphalt, etc.)
- Water

The "Hard Site" drop-off rate is typically considered to be 3 dB(A) per doubling of distance.

A "Soft Site" is an absorptive ground surface between the source and the receptor, such as:

- Grass/Lawn
- Loose Soil
- Snow

The "Soft Site " drop-off rate is typically considered to be 4.5 to 6 dB(A) per doubling of distance.

Calculate the noise level from a **Point Source** to a receptor 200 feet away if the noise level at 50 feet is 76 dB(A). Assume the ground surface is "soft". (Assume a drop off rate of 6 dB(A) per doubling of distance).

- 100 feet = 70 dB(A)
- 200 feet = 64 dB(A)

Let's try another one…..

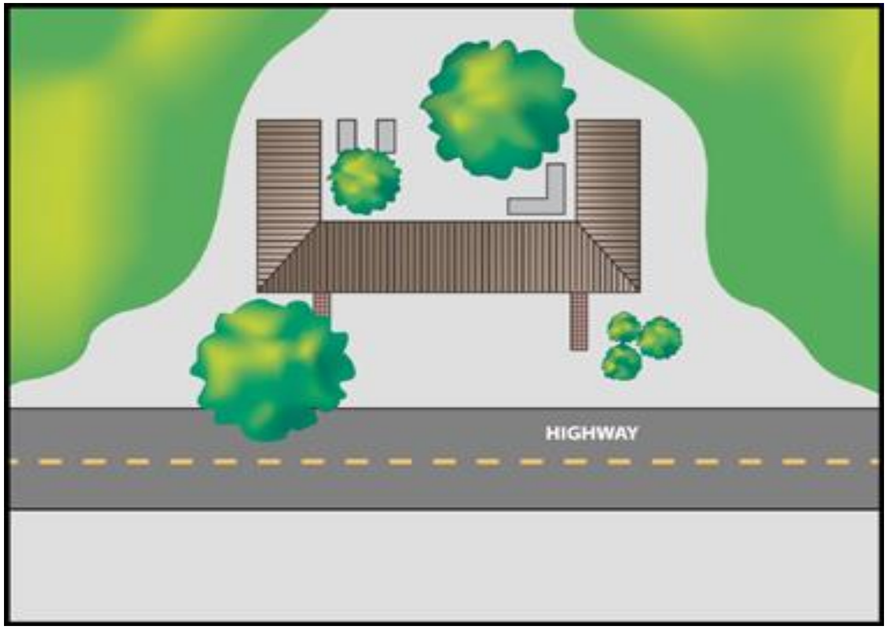
Calculate the noise level from a **Line Source** to a receptor 400 feet away if the noise level at 50 feet is 76 dB(A). (Assume this is a hard site with a drop off rate of 3 dB(A) per doubling of distance).

- 100 feet = **73** dB(A) **70**
- 200 feet = **70** dB(A) **64**
- 400 feet = **67** dB(A) **58**

What would you get if this were a soft site area? (Assume drop-off rate of 6 dB(A) per doubling of distance)

What is shielding?

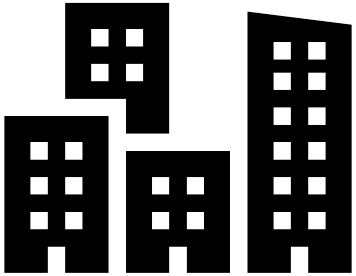
- Shielding is an object that exists between the noise source and the receiver that can reduce overall noise levels.

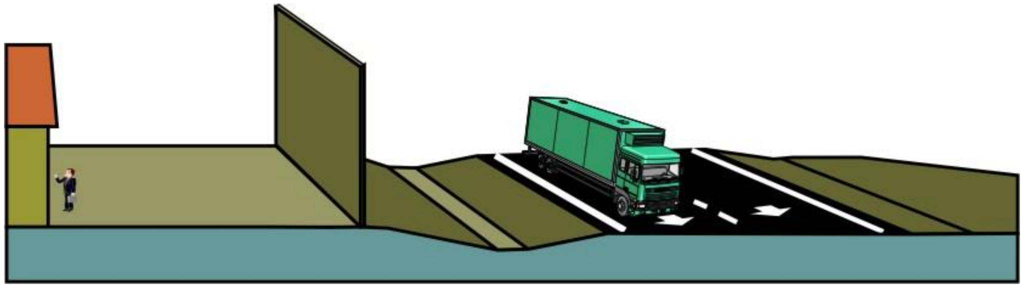


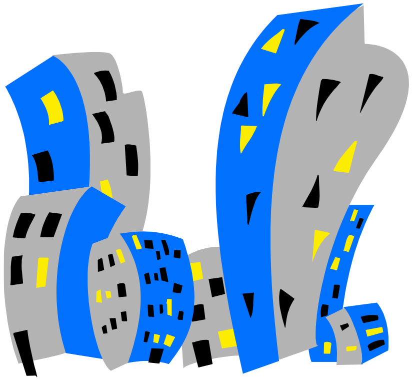
Source: FHWA

Examples of Shielding Include:

- Buildings/Rows of Homes
- Existing Barriers
- IMPORTANTLY!
  - FHWA does not consider the planting of vegetation to be a highway traffic noise abatement measure (see next slide)



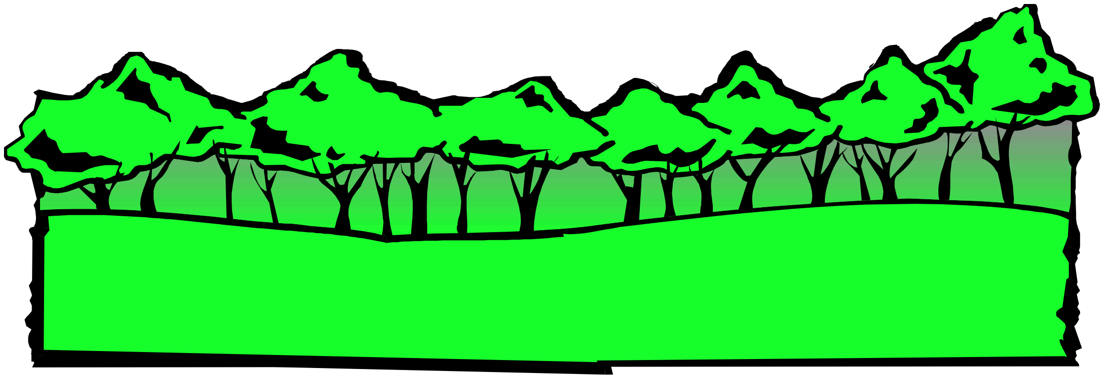




Vegetation and Traffic Noise

To reduce traffic noise, vegetation must be:

- 200 feet wide (between source and receptor)
  - According to FHWA – 10 dB(A) reduction
- "Optically Dense" (You can't see through it)



Shielding From Buildings and Rows of Homes

- Provided by buildings or rows of homes
- Will depend of the size of the structure(s) and the spacing between them

Shielding Can Also be Provided By Roadway Features, Such as:

- Elevated roadways on fill/embankment
- Elevated roadways on MSE/retaining walls
- The top edge of a depressed roadway (i.e., roadway in a "cut section"

Source: www.bigrbridge.com

Shielding from Building Envelope (Exterior to Interior Reduction)

- Will depend on the building construction
- In Florida, open windows are not typically modeled in the noise model
- …discussed in more detail in Lesson 3

Noise Reduction Provided by a Building

Building Type	Window Condition*	Noise Reduction Due to Exterior of the Structure
All	Open	10 dB
Light Frame	Ordinary Sash (closed)	20 dB
	Storm Windows	25 dB
Masonry	Single Glazed	25 dB
	Double Glazed	35 dB

*The windows shall be considered open unless there is firm knowledge that the windows are in fact kept closed almost every day of the year.

Source: FHWA Highway Traffic Noise: Analysis and Abatement Guidance, Table 6.

Windows are always considered closed in Florida

Noise Barrier Basics

How do they work?

By interrupting the direct noise path between the source and the receiver

FDOT

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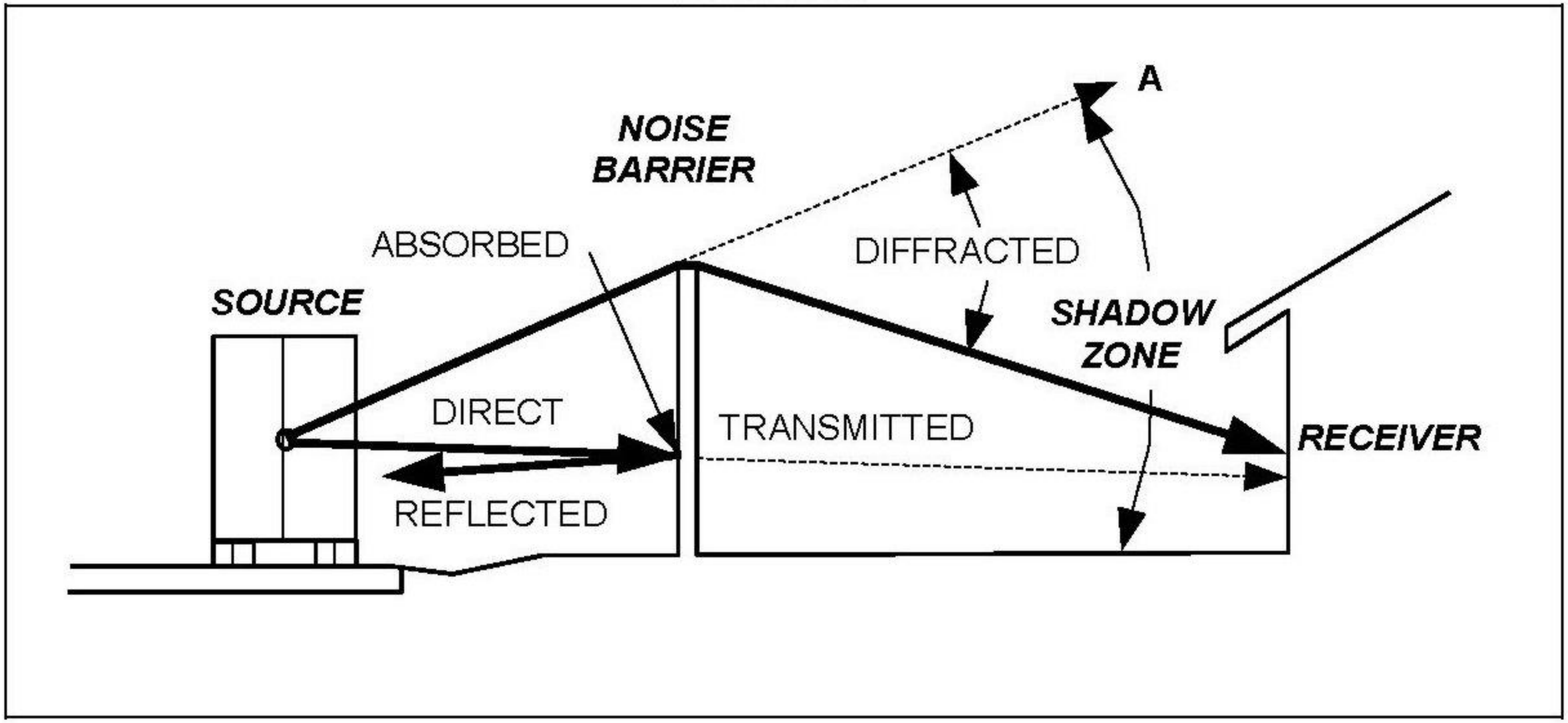


Source: CALTRANS Technical Noise Supplement, 1998

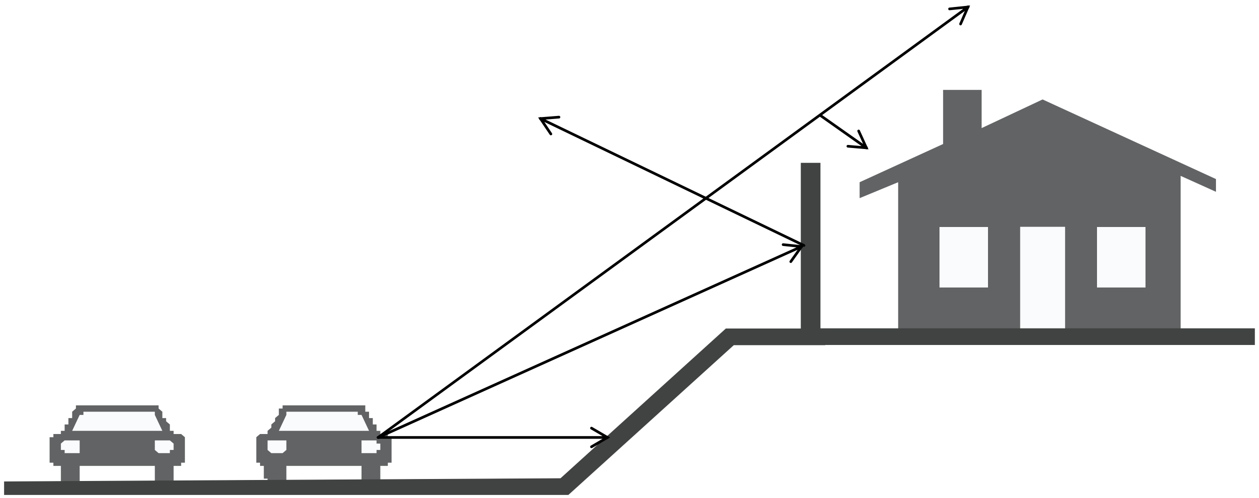
"Insertion Loss" (IL) is the difference in noise levels from the "before barrier" and "after barrier" conditions. Also referred to as "noise reduction" Includes all of the things we have discussed:

- Ground attenuation
- Reflected
- Diffraction
- Absorbed

Noise Barrier Placement

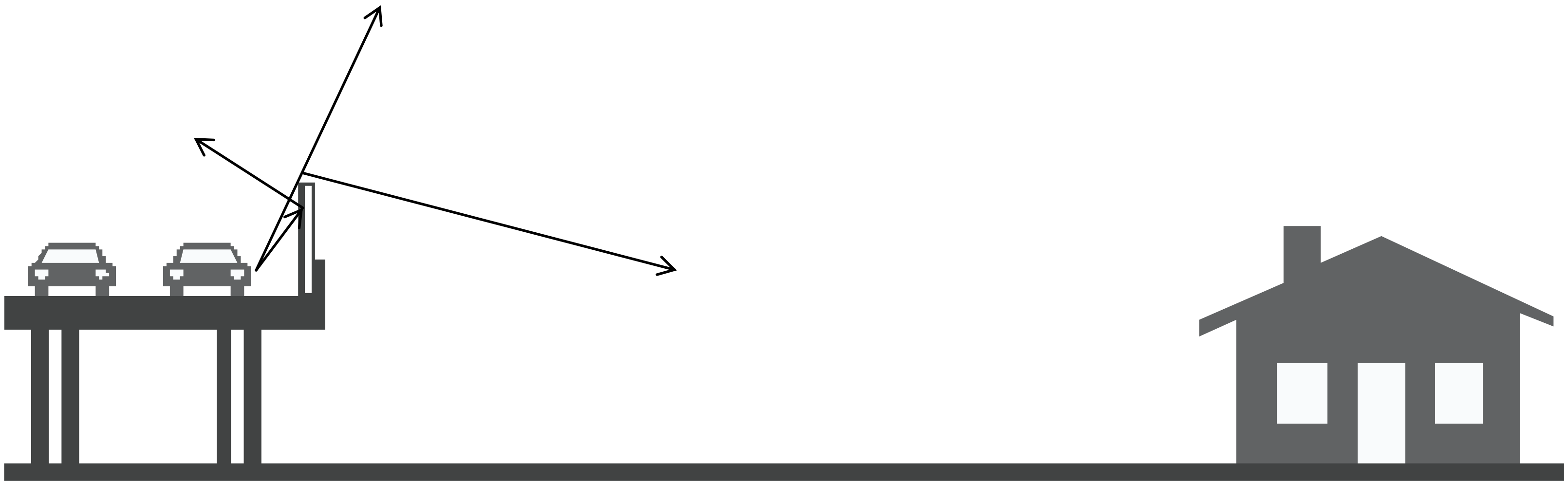
- As close to the receiver as possible
- If not, then as close to roadway as possible
- Avoid placing the noise barrier in the middle if at all possible.

If the roadway is depressed…



Noise barrier should be placed at the top of the cut slope, if possible

If roadway is elevated…



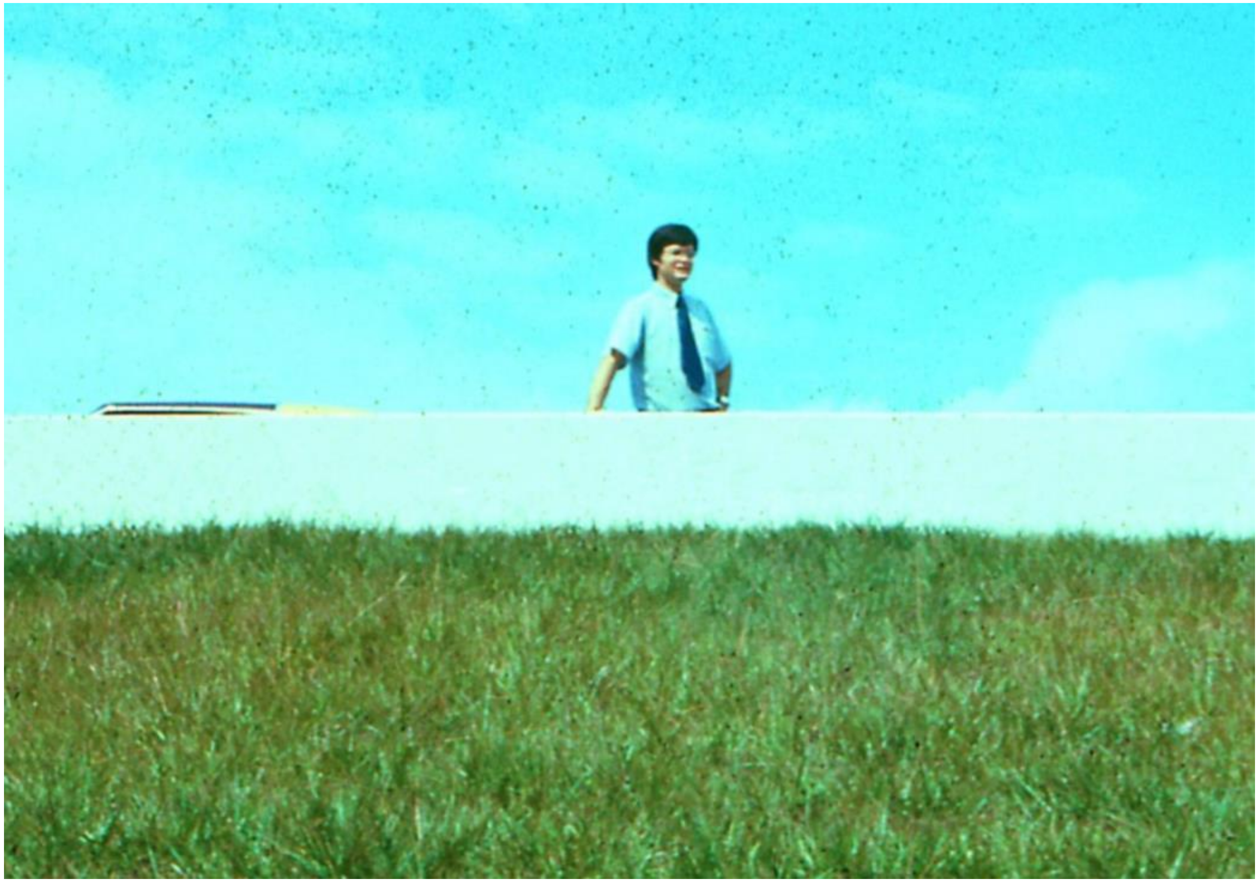
Noise barrier should be placed as close to the road as possible on elevated ground or structure.

How Tall Does the Noise Barrier Have to Be?

Many factors influence the height, but the general rule-of-thumb is…..

- The noise barrier has to at least break the line-of-sight to achieve a 5 dB(A) reduction in traffic noise
  - Line-of-sight is a straight line along which an observer has unobstructed vision to vehicles
- For each 2 feet above the initial break in line-of-sight, you will achieve approximately an additional 1 dB(A) reduction in traffic noise

Not an Effective Noise Barrier Design….



How Long Should the Noise Barrier Be?

As with the height, many factors will influence the length, but….

The general rule is that the barrier should extend "4D" beyond the last impacted receptor.

What is 4D??

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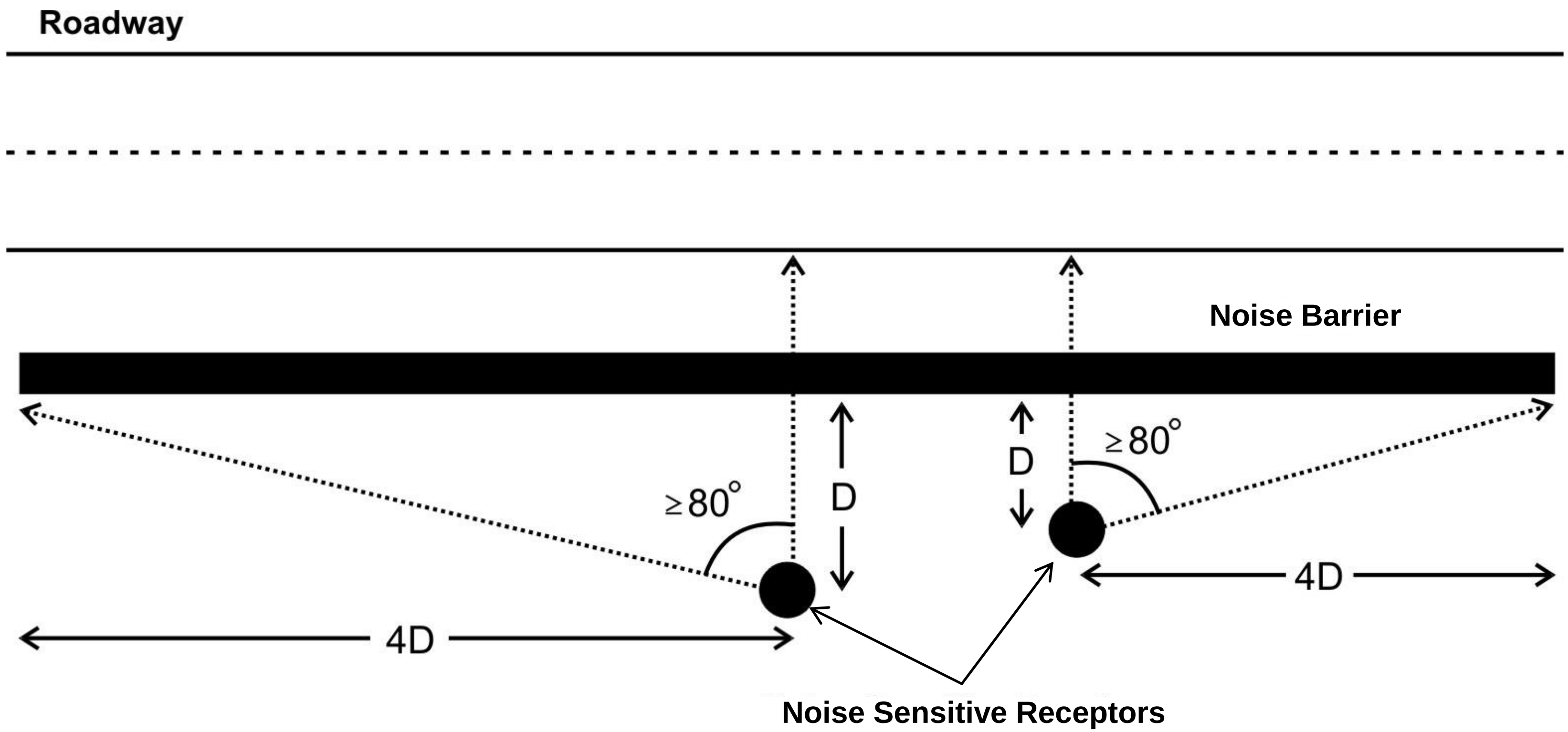
Noise Barrier Length



SOURCE: FHWA Highway Noise Barrier Design Handbook, 2000

QUESTIONS?

If you have any questions, please feel free to send an email to OEM@dot.state.fl.us