Calculation examples EMAQ Essentials of Noise 1

The following comprise examples of calculations that may be necessary for completion of the knowledge checks.

Distance Corrections

As distance gets larger, noise levels ***decrease***.

The rate of decrease is dictated by the type of source. Point source decay of sound due to distance is different from line and planar sources.

Point source example.

A machine has a sound pressure level of 60dB measured at 1m. what is the sound pressure level at 7.5m assuming a point source decay.

The relevant equation is
Lp1 = Lp2 – 20 log(r1/r2)

So:
Lp1 = 60 – 20 log(7.5/1)
Lp1 = 60 – 20 log (7.5)
Lp1 = 60 – 20 x 0.875
Lp1 = 60 – 17.5
Lp1 = 42.5dB

Line source example
If the machine were actually a long vibrating tube, and it behaved like a line source, the example above would be as follows:

The relevant equation is;
Lp1 = Lp2 – 10 log(r1/r2)

Lp1 = 60 – 10 log(7.5/1)
Lp1 = 60 – 10 log (7.5)
Lp1 = 60 – 10 x 0.875
Lp1 = 60 – 8.75
Lp1 = 51.3dB

The same equation would apply to a large vibrating plate, or the side of a building for planar decay due to distance.

NOTE:
The key issue is that line source decay of sound is slower than point source.
If we get sufficiently far away from a line source it actually behaves like a point source.

Adding and subtracting sound levels

Note this cannot be done with statistical measures such as LA90 as mathematically the result can be different.

Adding sound levels

Two or more sound levels that occur currently can be added together to predict a combine sound level.

For example, if two machines operate and create a sound level of 50dB at a receptor location, what is the combined sound level of both machines operated together?

The relevant equation is:
$dBsum = 10 \log (10^{L1/10} + 10^{L2/10} + 10^{L3/10} + \dots)$

so:
$dBsum = 10 \log(10^{5.0} + 10^{5})$
$dBsum = 10 \log (100000 + 100000)$
$dBsum = 10 \log (200000)$
$dBsum = 10 \times 5.3$
dBsum = 53dB

adding a third identical source would be:

$dBsum = 10 \log(10^{5.0} + 10^{5} + 10^{5})$
$dBsum = 10 \log (100000 + 100000 + 100000)$
$dBsum = 10 \log (300000)$
$dBsum = 10 \times 5.477$
dBsum = 54.8dB

adding a fourth identical source:
$dBsum = 10 \log(10^{5.0} + 10^{5} + 10^{5} + 10^{5})$
$dBsum = 10 \log (100000 + 100000 + 100000 + 100000)$
$dBsum = 10 \log (400000)$
$dBsum = 10 \times 5.6$
dBsum = 56dB

Doubling!

Rule of thumb

Double +3dB

Half -3dB

The general rule is that for each doubling of the number of sources, the level increases by 3dB as evidenced by the above, 1 source = 50dB, 2 is 53dB, 4 is 56dB.

The same basic equation is used for taking sounds away

Subtracting sound levels

In environmental noise this is used mainly to calculate the specific sound level in a BS4142 assessment. The residual noise is taken from the ambient noise to leave the specific noise level associated with the plant or equipment.

The relevant equation is
$dB = 10 \log (10^{L1/10} - 10^{L2/10} - 10^{L3/10} + \dots)$

For example, two machines are operating and the sound level is 60dB. we switch off one machine, the level drops by 2dB. what is the sound level of the other machine at that receptor location?

$dB = 10 \log (10^{6.0} – 10^{5.8})$
$dB = 10 \log (1000000 - 630957)$
$dBsum = 10 \log (369043)$
$dBsum = 10 \times 5.58$
$dBsum = 55.8dB$

NOTE:
You can add and subtract in the same equation if necessary. BUT that can lead to calculation error as folks forget +ve and -ve signs in the thrill of doing the calculations. My advice, keep them separate, and go through each stage!

Sound Power Conversions

Sound power is the power rating for a device or machine. Sound power to sound pressure conversion is based on the distance from the machine, and any defectivity effects. Acousticians use this frequently, particularly in modelling. You need to be aware of the basic calculations to be able to interpret results.

The relevant equations are:

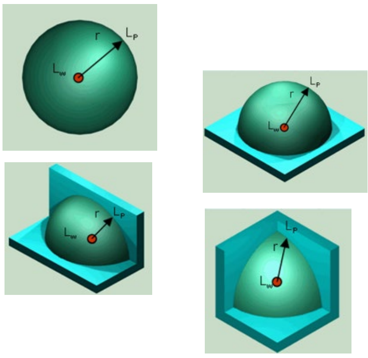
Sound Power conversion to Sound Pressure:

For $Q = 1$ is $L_W = L_p + [20 \times \log_{10} (r)] + 11$ dB (full)

For $Q = 2$ is $L_W = L_p + [20 \times \log_{10} (r)] + 8$ dB (half)

For $Q = 4$ is $L_W = L_p + [20 \times \log_{10} (r)] + 5$ dB (quarter)

For $Q = 8$ is $L_W = L_p + [20 \times \log_{10} (r)] + 2$ dB (eighth)



Often the requirement is to find sound pressure, so the equation needs to be manipulated to:

$Lp = Lw – [20 \times \log10 (r)] – 11$ dB (full) **(note the minus signs!)**

Example, the sound power of a machine is 60dB, it is placed on the floor but otherwise in the free field. What is the sound pressure level at 2, 4 and 8m?

$Lp = Lw – [20 \times \log_{10} (r)] – 8$ dB
$Lp = 60 – [20 \times \log 2] – 8$
$Lp = 60 – [20 \times 0.3] – 8$
$Lp = 60 – 6 – 8$
$Lp = 46dB$

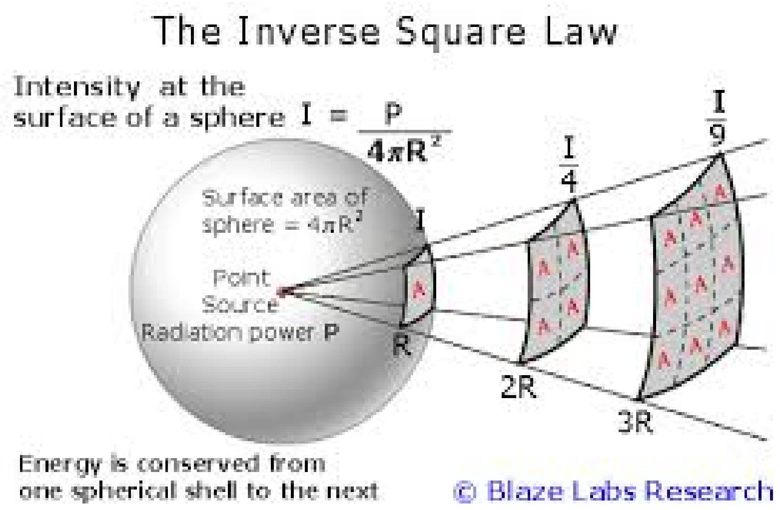
$Lp = Lw – [20 \times \log_{10} (r)] – 8$ dB
$Lp = 60 – [20 \times \log 4] – 8$
$Lp = 60 – [20 \times 0.6] – 8$
$Lp = 60 – 12 – 8$
$Lp = 40dB$

$Lp = Lw – [20 \times \log_{10} (r)] – 8$ dB
$Lp = 60 – [20 \times \log 8] – 8$
$Lp = 60 – [20 \times 0.3] – 8$
$Lp = 60 – 18 – 8$
$Lp = 34dB$

Rule of thumb. Double the distance from a sound source, - 6dB per doubling.

Line Sources, planar sources

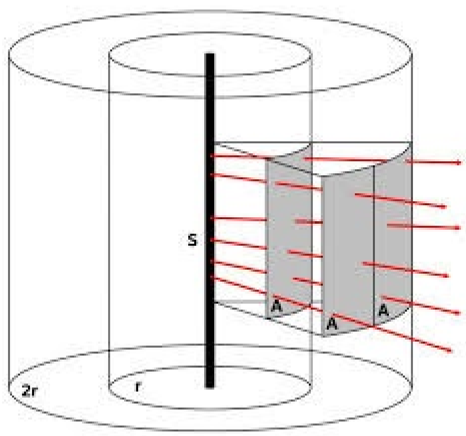
All sound reduces due to distance. But some sources reduce quicker than others. The equation above for a sound power calculation assumes that the source is a point source, i.e. small enough that the radiation of sound is equal in all directions and the sound energy radiates out equally at all points at a set distance…

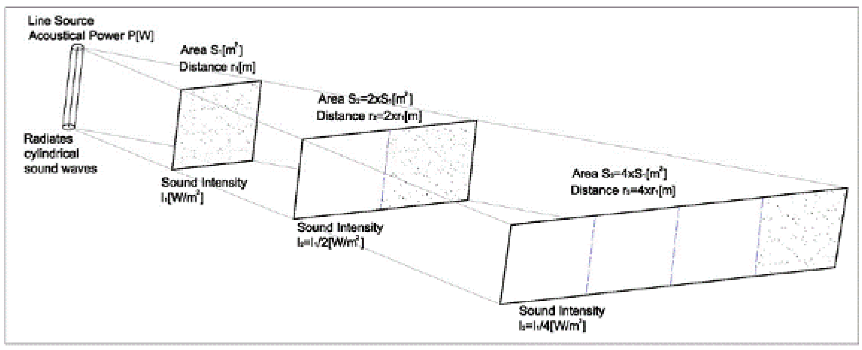


As you can see from the diagram, if this is true.. the sound power (innate energy of the source spreads out as a function of distance. Each additional distance there is less energy unit area (don't worry about the actual maths, it's the concept that's important), and energy perceived at each point anywhere around the sphere is the same. Three dimensional loss of energy.

This is fine where the source is small compared to the distances quoted. Most source, machines, gun shots, loud speakers, mobile phones, the list goes on, behave as point sources.

Some sources are different. They radiate energy along a line…. E.g. pipework, road and rail sources.

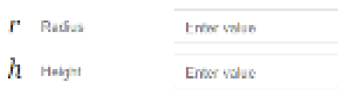


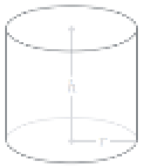


This is a diagram of a simple line source… a line array speaker in fact. Notice that unlike the example above, each doubling of distance the area of spread is smaller. It only radiates in 2 dimensions away from the source, not 3 dimensions as noted for a point source, we can see this by 'unwrapping' the cylinder (2nd diagram). This is significant because it affects how the energy is dispersed, i.e. there is no energy lost at the top and bottom only uniformly from the sides. The inverse square rule still applies, but the magnitude is different. It the energy is still lost over the surface area, but now the surface area is calculated based on a cylinder (with no ends) or rectangle and not a sphere.

Calculation of the surface area of a cylinder:

$$A = 2\pi r h + 2\pi r^2$$





This can be unfolded to a rectangle as circumference of the cylinder is the length dimension of the unfolded rectangle. Remember we aren't counting the ends… so the rectangle is (3.14 x r) length, x the height.

Assuming the cylinder is the same basic size as the sphere (height and radius the same), comparing the surface areas of both with a radius of 2m, and 4m we can see the difference

Distance	Sphere surface area = $A = 4\pi r^2$	Cylinder surface area = $A = 2\pi \mathrm{rh}$
For r = 2m	A = 4 x 3.14 x 2^2 A = 4 x 3.14 x 4 A = 50.25	A = 2 x (3.14 x 2) x 2 A = 25.12
For r = 4m	A = 4 x 3.14 x 4^2 A = 4 x 3.14 x 16 A = 200.96	A = 2 x (3.14 x 4) x 4 A = 100.48

The cylinder is exactly half the surface area of the sphere.

As this is a constant, this means that reduction in sound due to distance is ***half*** for a line source compared to a point source. You already know this because you can hear road traffic from miles away, but you couldn't hear someone shouting…

A planar source, like a line array speaker is a simpler issue because it is just a rectangular shape. Emitting sound, so the calculation is exactly the same as for a cylinder (only the dimensions are now measured height and measured length rather than as a function of π.

It is important that line sources and point source are addressed in the correct way to avoid what can be quite significant outcomes.

One final note. As you get further away from a line or planar source, it becomes small enough that it starts to behave like a point source. This is why that, at a certain point, the sound drops away more rapidly.

The above calculations are the only ones you really need to work check environmental acoustics!

But what about frequency…?

(You just know some know some smarty pants will remember this one!).

I did state that sound traveling over distance looses high and moderate frequencies as it travels. You may recall I mentioned the open air concert as an example, but equally fireworks, or road noise are also good examples.

The reason is simple enough. Sound expressed as a single number (like those above) is actually made up from the entire frequency spectrum. All the frequencies are present to a greater or lesser degree.

The physics of sound moving through the environment is therefore important. The environment is filled with material that the sound comes into contain with…

- The air, (and weather conditions)
- The ground
- Water
- Buildings
- Barriers
- Flora and fauna etc.
- …

Each of the materials will affect the sound in different ways and this is normally due to the frequency spectra the sound, which dictates how the sound will react to the material. High and moderate frequencies will tend to vibrate the objects, i.e. give up their energy when coming into contact with them. So as sound travels, we loose the high end frequencies first, due to absorption into the air, and the moderate frequencies into air/land/structures and finally the low frequencies last of all as they are mitigated the least by passage through environmental media.

You may have heard of Ultra Low Frequency (ULF) communication, that uses exactly this approach to communicate with submarines albeit with electromagnetic radiation, the principle is the same… think of a volcanic event, we feel the shock before we hear the event.

The calculations we went through at the start can be used to separate out the individual frequencies, (normally into octave or third octaves). Just remember that the sum total level of all the components does not exceed the total measured value!

Any other questions, please contact the EMAQ team for more help!

Tony Higgins 15.11.22 (update)