Course: MSc in Environmental and Architectural Acoustics
Unit: Measurement and Behaviour of Sound
Subject: Measurement of Sound Power Level

Aim

- To determine the sound power level of the source.
- To investigate directivity.

Additional Literature

1. ISO 3745 (precision method of sound power level measurements in anechoic or semi-anechoic rooms)
2. ISO 3744 (engineering method of sound power level measurements in anechoic or semi-anechoic rooms)
3. ISO 3740 (guidelines for operating and mounting conditions)

Instrumentation

1. CEL 593 Sound Level Meter
2. Microphone
3. Calibrator
4. Source (fan)

Introduction and Theory

A. Sound power Level, Lw

The sound pressure level or sound intensity level give a measure of the energy of a sound wave at a single point. The sound power level measures all the energy being radiated by a source in all directions. The sound power level is useful because it gives a measure of how much energy a source provides to an environment (inside a building, outside etc) and is independent of the environment the source is in. In contrast, the sound level depends very much on the environment it is in.

The are two measures:

	symbol		unit
Sound power	W	Linear value	Watts (W)
Sound power level	Lw	Logarithmic value	dB reference level 10^{-12} W

Relationship between sound power and sound power level

$$L_w = 10\lg\left(\frac{W}{10^{-12}}\right) dB, re10^{-12} W$$

$$W = 10^{-12} * 10^{\frac{L_w}{10}}$$

Relationship between sound power (W) and intensity (I)

$$W = \int_A I dA$$

Where A is an unbroken smooth surface that completely encloses the source, usually a sphere.

What this equation says is: if the intensity is a measure of the energy at a point, and we add up the energy for all points around the source, we get the total energy radiated from the source.

Spherical waves radiate uniformly in all directions from the source (similar to waves on the surface of a pond when a stone is thrown in the middle)

The sound level at a set radial distance (say 1m) from the source is always the same- uniform radiation. As spherical waves propagate the waves spread out and the energy in the waves gets distributed over a wider and wider area. Although the total energy of the source in all directions remains constant (sound power level constant), the energy at any point decreases with distance from the source (sound level decreases).

If we assume the surface is a sphere and radiates uniformly:

$$W = I * 4\pi r^2$$

Or rearranging we get an equation relating intensity and power to spherical waves:

$$I = \frac{W}{4\pi r^2}$$

Divide both sides by 10^{-12}, then take the logs of both sides and multiply by 10:

$$10Lg\left(\frac{I}{10^{-12}}\right) = 10Lg\left(\frac{W}{4\pi r^2 * 10^{-12}}\right)$$

Use definition of intensity level and log rule log(a/bc) = log(a/c) – log(b)

$$10Lg\left(\frac{I}{4\pi r^2}\right) + 10Lg\left(\frac{W}{10^{-12}}\right)$$

The intensity level (L_1) and SPL (Lp) in the free field are almost equal. (At ρc=400 N/m2 they are exactly equal).

Therefore,

$$L_p = L_w + 10Lg\left(\frac{1}{4\pi r^2}\right)$$

B. Directivity factor (Q) and Directivity Index (DI)

So far it has been assumed that the sources are radiating in free space. In reality there are usually reflecting surfaces close to the source. If the source lies on or very close to a surface, the effect of the surface can most simply be accounted for by using a directivity factor.

1. For a point source located near a large hard surface, the source can only radiate into a hemisphere:

$$I = \frac{W}{2\pi r^2} or, Q = 2$$

(in the experiment you will use Q=2)

2. For a line source located near two perpendicular large hard surface, the source can only radiate in to a ¼ sphere.

$$I = \frac{W}{\pi r^2} or, Q = 4$$

This can generally be represented by a directivity factor Q, and the intensity is given by:

$$I = \frac{QW}{4\pi r^2}$$

The directivity index, DI=10Lg(Q) is the logarithmic measure of the directivity factor

EQUATION.

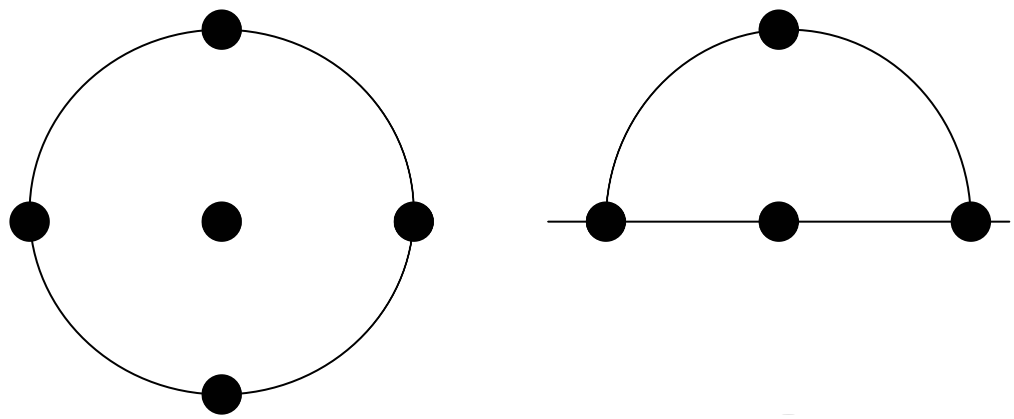
So given a source of known sound power level, it is possible to calculate the sound level it will generate when the source is placed in a known environment.

Procedure

1. Place the source in the centre of the anechoic room on the hard reflecting surface. Define five microphone positions that lie on the surface of a hemisphere centred on the source. Take measurements on a hemisphere of 2m radius at the following positions:

Mic. Position	X	Y	Z
1	0	0.87r	0.5r
2	0.87r	0	0.5r
3	0	-0.87r	0.5r
4	-0.87r	0	0.5r
5	0	0	r

Mics



Note: according to ISO 3745 you would have more microphone positions.

2. Measure SPL in 1/3 octave bands in the frequency range 100 to 5kHz plus A weighted at each measurement position.

Post-Processing

I) Determine the logarithmic average sound pressure level $\overline{L_p}$

II) Determine the sound power level Lw from the formula $\overline{L_p} = L_W + 10Lg\left(\frac{Q}{4\pi r^2}\right)$

III) Determine the directivity index (DI) at each point of measurement $DI_t = L_{P,i} - \overline{L_p}$ + 3dB (do it for A weighted level only). +3dB comes from the fact we are dealing with a hemisphere. In case of a sphere the +3 dB in the previous formula should be dropped. Note: generally in reports, it is sufficient to include only the highest DI and the direction it occurs. Here you are required to include DI for all directions.

IV) Now place the source in a corner of the anechoic chamber at approximately 1m from both the walls ands at 1.5m from the floor. Measure L_P at the following distances along the diagonal containing the source 0.1m 0.2m 0.4m 0.8m 1.6m 3.2m 4.8m.

Data to be presented and questions

1. Plot a graph of sound power against frequency in 1/3 octave bands, showing the A weighted L_W.
2. Comment on the directivity of the source. Does the source show any near field effects?
3. Over what distances does the inverse square law hold? Demonstrate graphically.