Sound Power – A Quick Reference

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First some definitions:

P **Sound Pressure** is expressed in Pascals. It is a measure of acoustic force per unit area. 1 Pa = 1 Newton per square meter (N/m^2)

W **Sound Power** is expressed in watts. It is the amount of acoustic energy a sound source produces per unit time.

I **Sound Intensity** expressed in watts per square meter (W/m^2). The rate sound energy flows through a unit area normal to the direction the sound is traveling.

$$\text{Sound Intensity} = \frac{SoundPower}{meter^2}$$

SPL **Sound Pressure Level**, is sound pressure expressed as dB relative to 20×10^{-6} Pascals (1 uPa).

SPL = 20 Log (P /20 uPa) dB

L_w **Sound Power Level** is expressed as dB relative to 10^{-12} Watts (1 picowatt).

L_w = 10 log (W / 1pW) dB

IL **Sound Intensity Level** is expressed as dB relative to 10^{-12} Watts/m^2 (1 picowatt/ m^2).

IL = 10 log (I / 1pW)/ m^2 dB

The following relationships are important:

One picowatt / square meter is the reference used for sound intensity level measurements.
1 pW is the intensity of a 1000 Hz tone at the threshold of hearing.

At 1 picowatt it can be shown that the effective sound pressure is 20.4 uPa which is rounded to 20 uPa for use as a reference for sound pressure measurements.

Therefore, because of the way the reference levels are defined, dB SPL and dB Sound Intensity Level are numerically identical in the free field.

For example 65 dB SPL = 65 dB IL in the free field. The relationship does not hold in non-free field conditions, in the near field or when standing waves exist.

Finding Sound Power of a device from Sound Pressure and Sound Intensity data:

1. Place the device under test on a flat hard surface in an anechoic or semi-anechoic environment. (Refer to hemisphere drawing Fig 2b).

2. Measure the SPL level at 10 microphone positions around the DUT, as shown. Typically this is done at a 1-meter distance. Free Field Microphones should be used.

3. Find the **average SPL** level of the 10 microphones:

   $$\mathbf{SPL_{avg}} = 10\log\left[\frac{1}{N}\sum_{i=1}^{N}10^{0.1Lpi}\right] \text{ dB}$$

   where N = Number of Mic positions
   L_{pi} = SPL measurement at each individual position, i.

4. In the free field, the Sound Intensity average is equal to the SPL average:

   $IL_{avg} = SPL_{avg}$ dB

5. Calculate the **sound power** , $\mathbf{L_w}$:

   $$\mathbf{L_w} = IL_{avg} + 10\log\left[\frac{S}{S_O}\right] \text{ dB}$$

   where S = total area of the measurement surface = $2\pi r^2$ for a hemisphere as in Fig 2.
   where S_O = the reference area, 1 meter square

For example:

A device is placed on a large flat table and SPL measurements are made at a distance of 1 meter using 10 microphones at the points shown on the imaginary hemisphere of Fig. 2.
For simplicity, lets say the device under test radiates sound <u>equally</u> in all directions and all 10-microphones measure 76 dB SPL. The average SPL would be 76 dB SPL and the average Sound Intensity would also be 76 dB. In this example the radius, r, is 1 meter.

$$\mathbf{L_w} = IL_{avg} + 10\log\left[\frac{S}{S_O}\right] = 76 + 10\log\left[\frac{2\pi 1^2}{1}\right] \text{ dB} = 76 \text{ dB}+7.98 \text{ dB} = 84 \text{ dB rel 1 pW}$$

If A-weighted sound power is required then the SPL measurements should be A-weighted.

If the measurement radius, r, = 1.26 meters then $\mathbf{L_w} = IL_{avg}$ + 10 dB.

Note that, ideally, each microphone covers the same measurement area on the hemisphere.

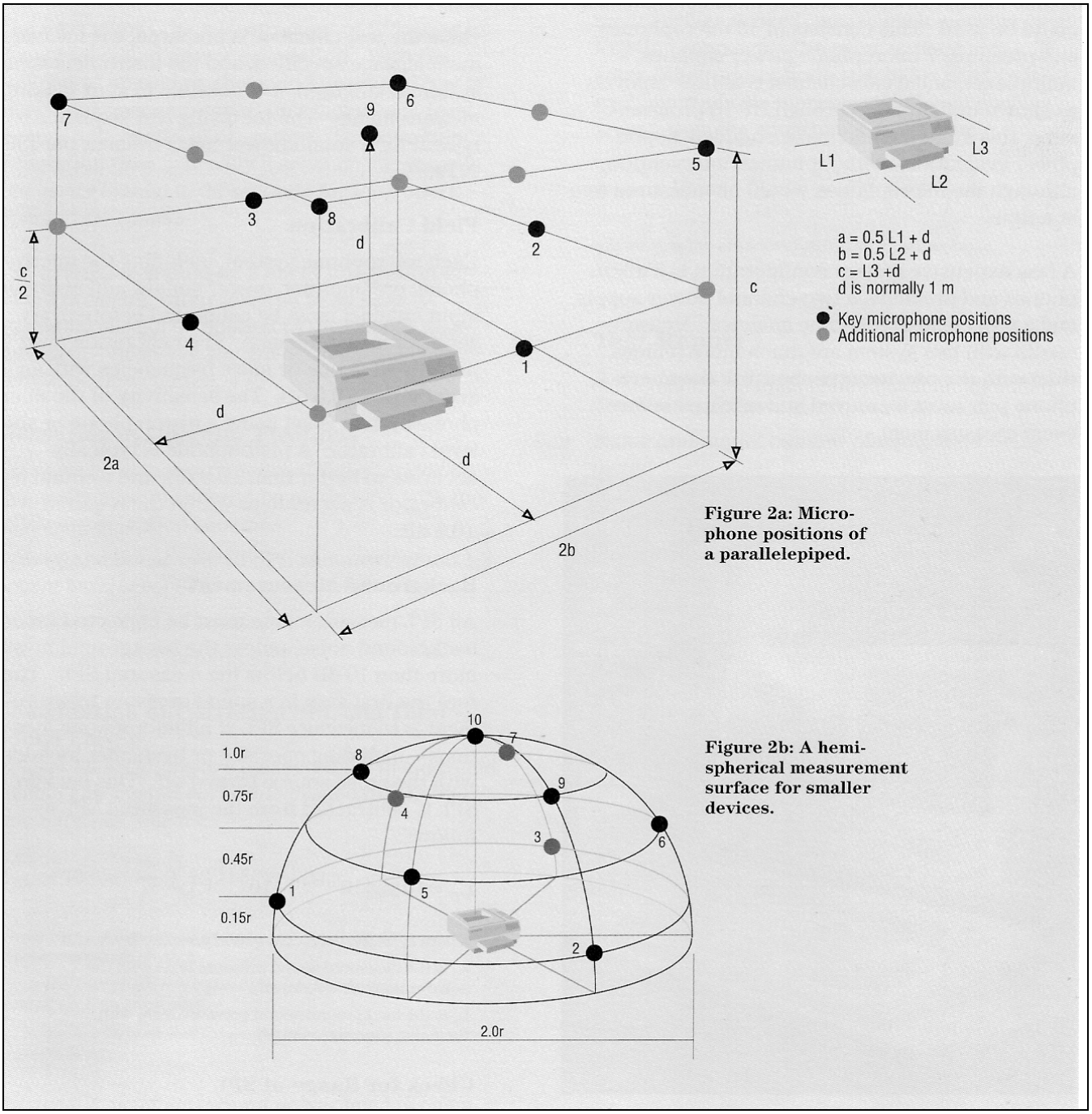

Fig 2 - Microphone Positions on the imaginary measurement surface
From Hewlett Packard App Note 1230 *Sound Power Measurements*