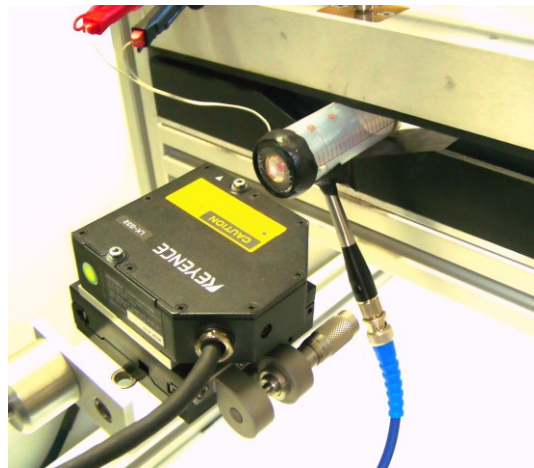


FEATURES

- Calculation of effective radiation area over frequency
- Two measurement methods for constant and differential volume

BENEFITS

- Precise determination of the radiation area especially for small speaker types.
- Simple measurement method and postprocessing



DESCRIPTION

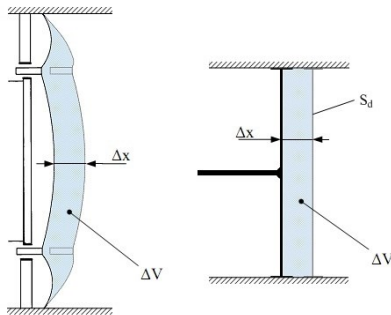
Plenty of applications need to specify the effective radiation area of the speaker, which is the surface area of an equivalent piston. For usual drivers like woofers the effective radius can just be estimated, but more complex constructions, e.g. microspeakers should be measured. This paper explains two methods for either a simple measurement with a constant volume of the box or a two-step difference measurement where the volume is changed. Step-by-step instructions are provided on how to calculate the effective radiation area using predefined Klippel templates. In addition, an example is presented to demonstrate a measurement of a headphone microspeaker using an injection as a variable enclosure.

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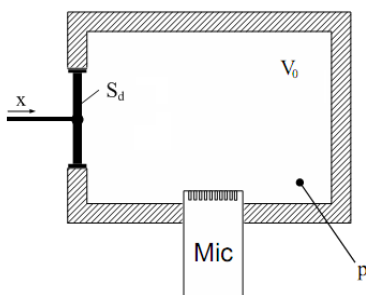
1 Terms and Definitions

Effective Radiation Area



At sufficiently low frequencies every loudspeaker can ideally be represented as an infinitely rigid piston, which displaces the same air volume ΔV at a constant voice coil displacement Δx . The area of this piston is always smaller than the real cone area and it is characterized as the effective radiation area S_d with the effective radius r_d .

The Pistonphone Principle



$$p = \frac{S_d}{N_a} x = \frac{p_0 S_d \kappa}{V_0} x$$

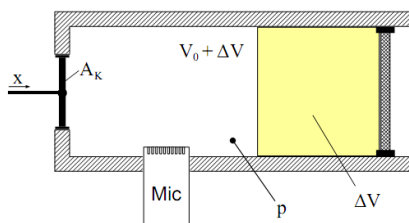
$$S_d = \frac{V_0}{p_0 \kappa} \frac{p}{x}$$

A pistonphone is usually used as an apparatus for microphone calibration. It simply consists of a closed volume V_0 producing an acoustical compliance N_a and a rigid piston with the surface S_d . Sinusoidally excited with a constant peak displacement x the piston generates a constant peak sound pressure p inside the volume using:

- adiabatic coefficient κ
- static air pressure p_0

We use this principle inversely to determine the effective radiation area S_d of the actuator by measuring the sound pressure inside the enclosure and the displacement in the center of the cone.

Differential measurement





$$S_d = \frac{\Delta V}{p_0 \kappa \left(\frac{x_2}{p_2} - \frac{x_1}{p_1} \right)}$$

Using two measurements in different volumes it is not necessary to determine the absolute volume V_0 of the air in the enclosure where the driver is mounted. The absolute volume is replaced by the variation ΔV of the air volume.

For microspeakers you may use a syringe (medical injection pump) for example, so you may change the volume and read its difference within a few seconds.

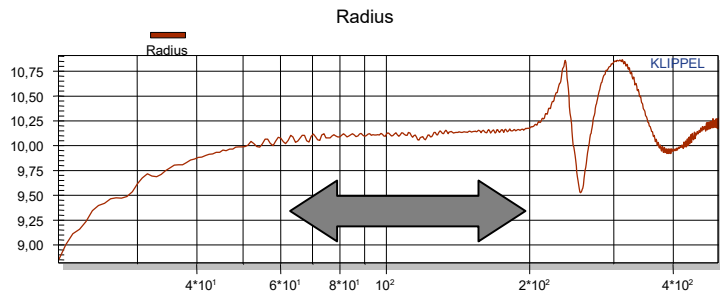
2 Requirements

Speaker Enclosure	<p>The enclosure of the speaker has to be sealed and airproof. There should only be one hole which is slightly wider than the diameter of the measurement microphone used. You can decide if you want to measure with one constant volume, which has to be specified or you use two different enclosures to calculate the effective radiation area with the volume difference. Klippel provides a dedicated dB-Lab template for each method.</p> <p>Measuring with one constant enclosure volume will be easier and faster, but you have to keep in mind that you have to know the exact volume with regard of the driver parts inside the box.</p> <div data-bbox="475 654 847 972">  </div> <p>Because of the intricate construction of the drivers we recommend to perform two measurements in different volumes if you do not know the volume of the driver. A quite simple possibility for a microspeaker is using a syringe, which allows an easy metering of the volume difference. You may cut off the orifice to place the driver and drill two holes for the microphone and the cables. We recommend using a second volume which is about 1.5 to 3 times as big as the first one. Seal all holes and fix the driver and the microphone with plasticine or similar.</p>						
Hardware / Software	<p>To measure and calculate the Effective Radiation Area the following hardware and software is required:</p> <table border="1" data-bbox="475 1205 1417 1487"> <tr> <td data-bbox="475 1205 683 1379">Hardware</td><td data-bbox="683 1205 1417 1379"> <ul style="list-style-type: none"> ○ Klippel Analyzer hardware (DA2 or KA3) ○ measurement microphone ○ laser displacement sensor (Keyence LK-H052 is recommended for small displacement) </td></tr> <tr> <td data-bbox="475 1379 683 1435">Software</td><td data-bbox="683 1379 1417 1435"> <ul style="list-style-type: none"> ○ dB-Lab 210 or higher * </td></tr> <tr> <td data-bbox="475 1435 683 1487">Licenses</td><td data-bbox="683 1435 1417 1487"> <ul style="list-style-type: none"> ○ TRF – Transfer Function (Standard or Pro) </td></tr> </table>	Hardware	<ul style="list-style-type: none"> ○ Klippel Analyzer hardware (DA2 or KA3) ○ measurement microphone ○ laser displacement sensor (Keyence LK-H052 is recommended for small displacement) 	Software	<ul style="list-style-type: none"> ○ dB-Lab 210 or higher * 	Licenses	<ul style="list-style-type: none"> ○ TRF – Transfer Function (Standard or Pro)
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Software	<ul style="list-style-type: none"> ○ dB-Lab 210 or higher * 						
Licenses	<ul style="list-style-type: none"> ○ TRF – Transfer Function (Standard or Pro) 						
Preparation	<ul style="list-style-type: none"> • Open a dB-Lab database and create a new object  from the template <i>Eff Radiation Area - diffV</i> for a differential measurement or <i>Eff Radiation Area - absV</i> for a measurement with one constant volume. • Enter the sensitivity of the microphone in the property page <i>Input</i> for each <i>TRF</i> measurement or use a pistonphone to calibrate the microphone. • Calibrate your laser sensor (see the Hardware Manual for instructions how to do this for your Klippel Analyzer hardware). 						

* for dB-Lab version ≤ 206 there is an older version of this AN available

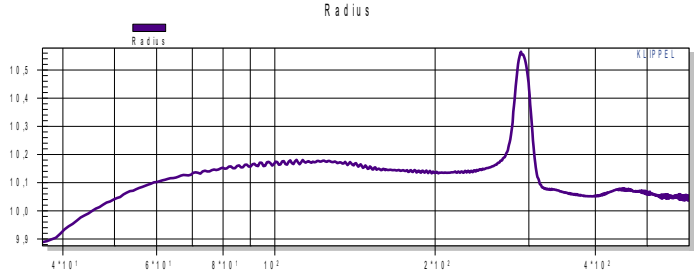
3 Differential Measurement

Template: Eff Radiation Area – diffV

Motivation	<p>The main advantage of the differential measurement technique is that it is not necessary to determine exactly in which way the loudspeaker influences the box volume. This should be similar for every enclosure. When using a syringe it is even negligible how the driver and the microphone are fixed inside the enclosure.</p> <p>The differential volume can easily be evaluated via the volumes of the empty boxes or just be read off the scale of the syringe.</p>
Measurement of the Displacement to SPL ratio	<p>How to do it: Set the measurement microphone in the allocated port so that the capsule is inside the enclosure. Adjust the laser sensor to the center of the driver. In <i>Properties</i> → <i>Stimulus</i> of the operation <i>TRF 1st volume</i> determine your stimulus voltage according to your driver.</p> <p>Run the <i>TRF 1st volume</i> measurement.</p> <p>Make sure that you have selected the transfer function $H(f) = X / IN$ in <i>Properties</i> → <i>Processing</i> and use <i>No Window</i>.</p> <p>Please check that the distance between the <i>Noise floor</i> and the <i>Signal lines</i> in the windows <i>Y1 (f) Spectrum</i> and <i>Y2 (f) Spectrum</i> is at least 20dB in the frequency range of interest. Otherwise please either increase the stimulus voltage or the number of averages to get better SNR.</p> <p>For the second volume perform the <i>TRF 2nd volume</i> measurement with exactly the same parameters in <i>Properties</i>.</p> <p>Note: Keep in mind that you have to open one hole for pressure compensation while changing the volume of the syringe. Naturally the curve progression should be similar to the first measurement considering an offset of some dB.</p>
Calculating the Effective Radiation Area	<p>How to do it: Open the <i>properties</i> of operation <i>PPP Radiation Area</i> and enter the difference of both volumes <i>deltaV</i> in [ml] and determine your frequency bounds <i>fmin</i> and <i>fmax</i> for averaging the effective radiation area. It is recommended using a wide frequency band first (similar to your measurement sweep) and repeating the calculation in a band where you can detect a good linearity.</p> <p>Click the green arrow in the dB-Lab toolbar to run the calculation.</p>
Results	 <p>The <i>Result Table</i> window will return the effective radiation area and the equivalent radius averaged over your determined bandwidth. The window <i>Radius</i> shows the effective driver radius in terms of frequency. Ideally it would be a plane curve, but you may change your frequency bounds to select an almost plane area of the curve (in the example above between 60 and 200 Hz) and repeat your calculation to obtain a more exact solution.</p>

4 Measurement in a constant volume

Template: Eff Radiation Area – absV

Motivation	If you exactly know the air volume enclosed by test box and diaphragm of the driver it is the easiest and fastest way to measure the effective radiation area. Only one TRF measurement and a simple calculation afterwards are required.
Measurement of the SPL to Displacement ratio	<p>How to do it: Set the measurement microphone in the allocated port so that the capsule is inside the enclosure and seal the gap between microphone and enclosure. Adjust the laser sensor to the center of the driver. Open <i>Properties</i> → <i>Stimulus</i> of operation $TRF\ H(f) = SPL/X$ and adjust the stimulus voltage according to the driver.</p> <p>Run the $TRF\ H(f) = SPL/X$ measurement.</p> <p>Make sure that you have select the transfer function $H(f) = IN / X$ in <i>Properties</i> → <i>Processing</i> and use <i>No Window</i>.</p> <p>Please check that the distance between the <i>Noise floor</i> and the <i>Signal lines</i> in the windows <i>Y1 (f) Spectrum</i> and <i>Y2 (f) Spectrum</i> is at least 20dB in the frequency range of interest. Otherwise please either increase the stimulus voltage or the number of averages to get better SNR.</p>
Calculating the Effective Radiation Area	<p>How to do it: Open the <i>Properties</i> of operation <i>PPP Radiation Area</i> and enter the absolute volume V_0 of your box in [ml] and determine optimal frequency bounds f_{min} and f_{max} for averaging the effective radiation area. It is recommended using a wide frequency band first (similar to your measurement sweep) and repeating the calculation in a band where the calculated value is almost constant.</p> <p>Click the green arrow in the dB-Lab toolbar to run the calculation.</p>
Results	 <p>The <i>Result Table</i> window will return the effective radiation area and the equivalent radius averaged over your determined bandwidth. The window <i>Radius</i> shows the radius in terms of frequency. Ideally it would be a plane curve, but you may change your frequency bounds to select an almost plane area of the curve (in the example above between 70 and 250 Hz) and repeat your calculation to obtain a more exact solution.</p>

5 References	
Literature	A.Lenk, G.Pfeifer, R.Werthschützky (2001) "Elektromechanische Systeme", chapter 3.3.6.1 „Pistonfon“, Springer, Heidelberg
Related Application Notes	[1] AN24 - Measuring Telecommunication Drivers [2] AN25 - Maximizing LPM Accuracy

Find explanations for symbols at:

<http://www.klippel.de/know-how/literature.html>

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