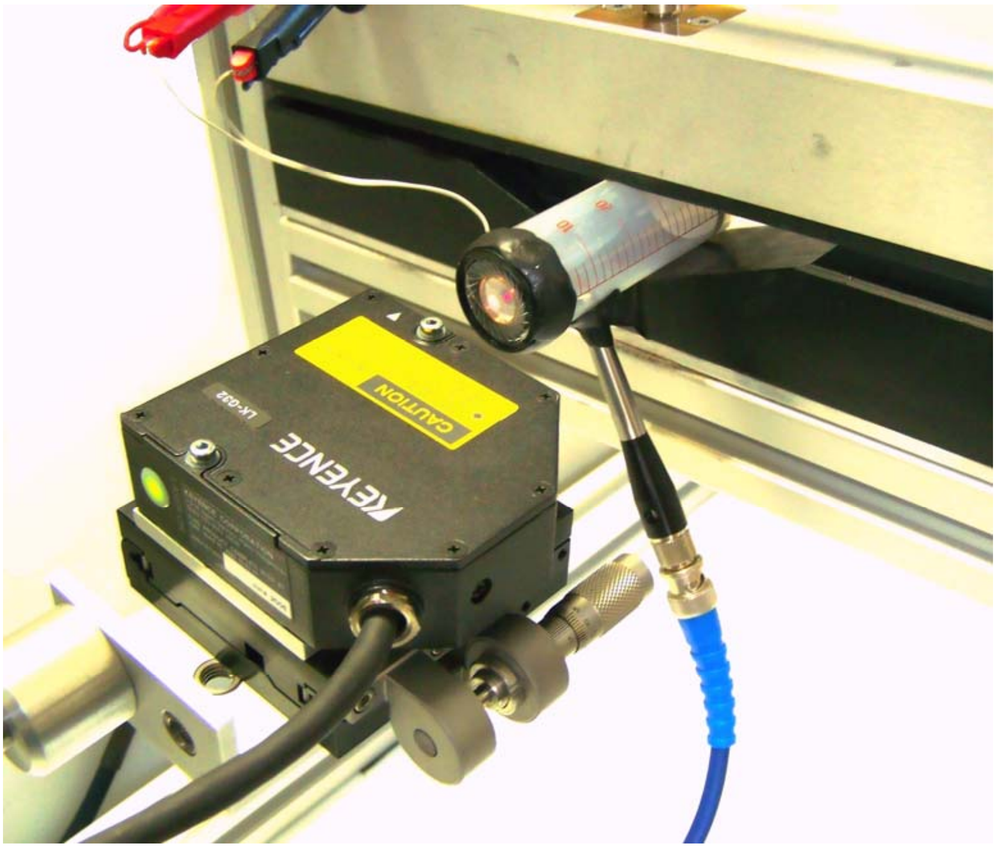
Effective Radiation Area S_d **AN 32**

Application Note to the KLIPPEL R&D SYSTEM

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. For this purpose Klippel provides two templates for either a simple measurement with a constant volume of the box or a two-step difference measurement where the volume is changed. The difference measurement gives more accuracy when the geometry of the driver is complex and absolute air volume is not known.

This Application Note is a step by step introduction for both methods of measurement and calculation of the effective radiation area with the Klippel templates *Eff Radiation Area – diffV* and *- absV*. An example is presented to demonstrate a measurement of a headphone microspeaker using an injection as a variable enclosure.



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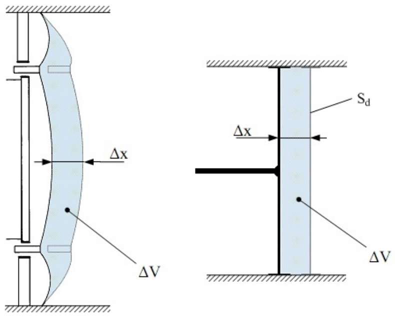
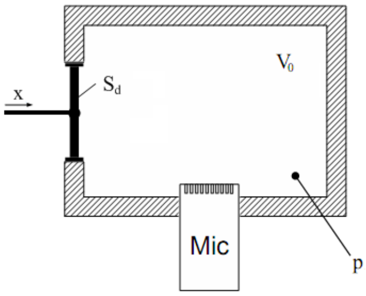
Terms and Definitions

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



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

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

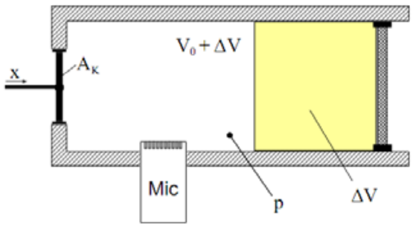
A pistonphone is usually used as an apparatus for microphone calibration. It simply consists of a closed volume V_0 producing an acoustical compliance N_a and a rigid piston with the surface S_d. Sinusoidally exited with a constant peak displacement x the piston generates a constant peak sound pressure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

Requirements

Speaker Enclosure	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 different template for each method. 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 and regard the driver parts inside the box.  Because of the intricate construction of the driver 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.
Start Up	To measure and calculate the Effective Radiation Area the following equipment is required: • Install the RnD analysis software on your computer. • Create a new object and select the template *Eff Radiation Area - diffV* for a differential measurement or *Eff Radiation Area - absV* for a measurement with one constant volume to start the analysis. • Enter the sensitivity of the microphone in the Input property page for each *TRF* measurement or use a pistonphone to calibrate the microphone. • Calibrate your laser in stand alone mode of your *Distortion Analyzer* (according to RnD Manual).

Differential Measurement

Template: Eff Radiation Area – diffV

Motivation	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. The differential volume can easily be evaluated via the volumes of the empty boxes or just be read off the scale of the syringe.
Measurement of the Displacement to SPL ratio	**How to do it:** Set the measurement microphone in the allocated port so that the capsule is inside the enclosure and adjust the laser normal to the center of the driver. In *Properties → Stimulus* of the *TRF 1st volume* determine your stimulus voltage according to your driver and the laser. Run the *TRF 1st volume* measurement. Make sure that you have selected the transfer function $H(f) = X / IN$ in *Properties → Processing* and use *No Window.* For the second volume perform the *TRF 2nd volume* measurement with exactly the same parameters in *Properties.* 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.

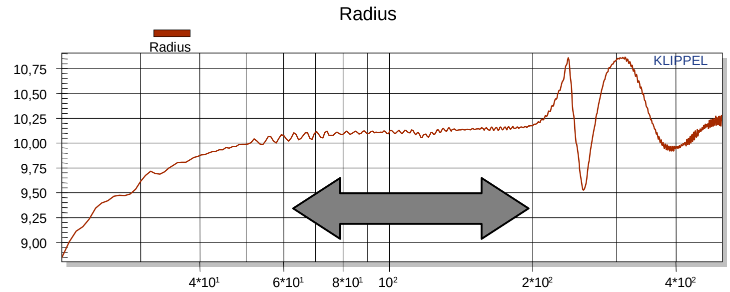
Calculating the Effective Radiation Area

How to do it: In *Properties* → *Im/Export* of *TRF 1st volume* select *H(f) + Total phase* and export them to clipboard. Open the *Radiation Area diffV* calculation, select *X_SPL_CurveA* in *Properties* → *Input* and press *Paste*. Repeat this step to copy the curve of *TRF 2nd volume* to *X_SPL_CurveB*.

Enter the difference of both volumes *deltaV* in ml and determine your frequency bounds *fmin* and *fmax* for averaging the effective radiation area. We recommend to use a wide band first (similar to your measurement sweep) and repeat the calculation in a band where you can detect a good linearity.

Click the green arrow in the dB-Lab toolbar to run the calculation.

Results



The *Result Variables* window will return the effective radiation area and the equivalent radius averaged over your determined bandwidth. *Result Curve 2* shows the radius in terms of the 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.

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

How to do it: Set the measurement microphone in the allocated port so that the capsule is inside and seal the enclosure. Adjust the laser normal to the center of the driver Adjust the stimulus voltage according to the driver in *Properties* → *Stimulus* of the *TRF H(f) = SPL/X*.

Run the *TRF H(f) = SPL/X* measurement.

Make sure that you have select the transfer function H(f) = IN / X in *Properties* → *Processing* and use *No Window.*

When finished the measurement and processing you may go to *Properties* → *Im/Export* and export *H(f) + Total phase* to clipboard.

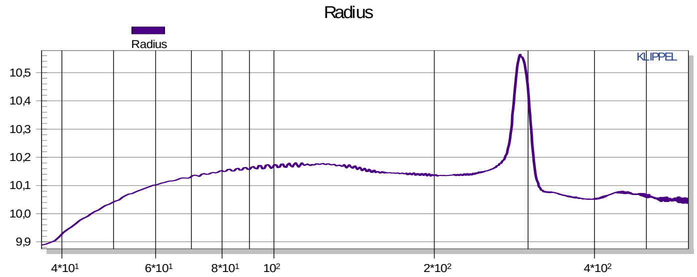
Calculating the Effective Radiation Area

How to do it: Open the *Radiation Area absV* calculation, select *SPL_X_Curve* in *Properties* → *Input* and press *Paste*.

Enter the absolute volume *V0* of your box in 'ml' and determine optimal frequency bounds *fmin* and *fmax* for averaging the effective radiation area. We recommend to use a wide band first (similar to your measurement sweep) and repeat the calculation in a band where the value is almost constant.

Click the green arrow in the dB-Lab toolbar to run the calculation.

Results



The *Result Variables* window will return the effective radiation area and the equivalent radius averaged over your determined bandwidth. *Result Curve 2* shows the radius in terms of the 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.

More Information

Literature

A.Lenk, G.Pfeifer, R.Werthschützky (2001) “Elektromechanische Systeme”, chapter 3.3.6.1 „Pistonfon“, Springer, Heidelberg

Related Application Notes

[1] AN32 - Effective Radiation Area S_d

[2] AN24 - Measuring Telecommunication Drivers

[3] AN25 - Maximizing LPM Accuracy

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