Buenos Aires – 5 to 9 September, 2016
Acoustics for the 21st Century…

PROCEEDINGS of the 22nd International Congress on Acoustics

Electroacoustics and Audio Engineering: Paper ICA2016-655

Measurement of the contribution to the acoustical impedance of a loudspeaker due the internal cavities in magnetic circuit using an impedance tube

Jorge Moreno[(a)], Richard Rivera[(b)], Celso Llimpe[(c)]
[(a,b,c)] Acoustics Laboratory, Physics Department, Pontificia Universidad Católica del Perú, Lima, Perú
jmoreno@pucp.edu.pe, rrivera@pucp.edu.pe, cllimpe@pucp.edu.pe

Abstract

The acoustical back loading due to the inner cavities of the magnetic circuit can influence in the frequency response of a loudspeaker, therefore in order to optimize the design; it is useful to know the behavior of this loading. In this paper, it is shown that it is possible to measure the acoustical impedance of single elements or combination of these, e.g. resonators located inside the magnetic circuit using an impedance tube. The method presented here is meant to be used in the development stage of the loudspeaker when it is still possible to remove the voice coil or to close partially or totally some of the inner cavities.

Keywords: cavities, acoustic impedance, magnetic circuit

1 Introduction

The cavities within the magnetic circuit of a loudspeaker can influence in the frequency response of the transducer if they resonate. Inside the magnetic circuit, tubes and volumes are interconnected forming resonators; these elements can absorb energy in the frequency range reproduced by the loudspeaker creating irregularities in the frequency response.

These parasitic resonances are particularly problematic during the design process of mid-range units, tweeters and compression drivers [1], so it is desirable to identify these problems.

Here the use of an impedance tube to measure the acoustic impedance of the cavities within the magnetic circuit is presented. Some other authors had already proved that it is possible to measure similar elements [2]. This technique allows measuring the resonances of single volumes and tubes as well as combinations of these elements in a loudspeaker.

It is a common practice to fill some of the cavities or tubes with porous materials or add some other kind of acoustic resistance to damp the resonances.

With this measurement it is possible to find the frequencies at which the cavities resonate and quantify the effect of the absorbing materials added, as well as the value of its acoustic impedance.

It should be possible to measure smaller devices if an impedance tube with the right dimensions and the correct microphone distance is used [3].

2 Extended linear loudspeaker model

The classical linear lumped parameter model of a loudspeaker do not consider the back loading of the cavities present in the magnetic circuit, Figure 1 show a scheme of a typical cross section of a loudspeaker showing all the cavities within the magnetic circuit, these compliances, acoustic mases and resistance will be part of the back acoustic loading of the loudspeaker, this loading will change if the geometry of the magnetic circuit changes, this can be the case of magnetic circuits designed with Neodymium magnets, in which case the model has to be modified, but the way to measure should remain the same.

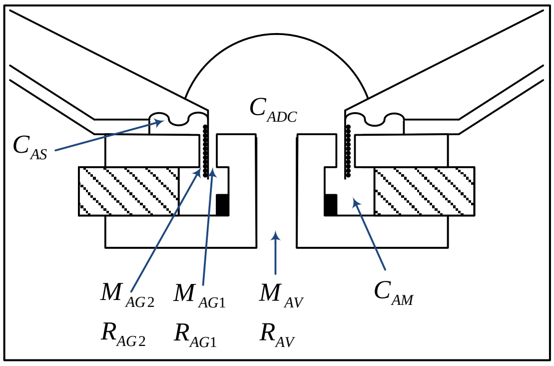


Figure 1. Cross section of a loudspeaker showing all the cavities within the magnetic circuit

The impedance type equivalent electric circuit corresponding to the scheme showed in Figure 1 is shown in Figure 2. The equivalent circuit includes the viscoelastic effect of the suspension and the back acoustic loading due to the magnetic circuit cavities.

The dust cup, the cone and the spider has been considered as separate radiators, it has been considered that the dust cup with the portion of cone under the dust cup plus the cylinder formed by the voice coil former and the pole of the magnetic circuit, generate a compliance that will resonate with the vent of the magnetic circuit.

The gap is split in two slits by the voice coil, in the case analyzed here the two slits do not have the same width, due to the manufacturing process. Via one of the slits, the compliance C_{ADC} communicate with C_{AM} and via the other slit the compliance C_{AS} communicates with C_{AM}.

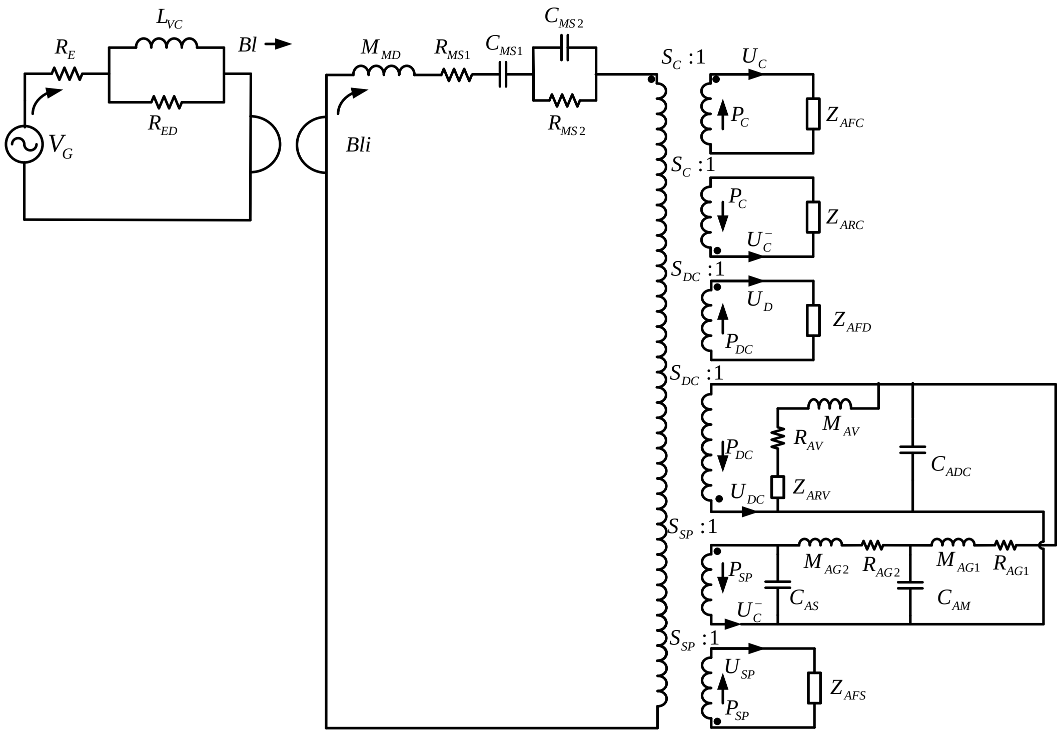


Figure 2. Impedance type equivalent electric circuit corresponding to the scheme showed in Figure 1, the circuit includes the viscoelastic effect of the suspension and the acoustic back loading due to the magnetic circuit cavities.

Where:

V_G	Source voltage
R_E	Voice coil DC resistance
L_{VC}	Voice coil inductance
R_{ED}	Resistance that represents the effect of Eddy currents in the magnetic circuit
M_{MD}	Mechanical mass of the diaphragm, including voice coil, excluding the acoustic radiation load

R_{MS1}	Mechanical resistance component (TGM)[1] model, Voigt branch
C_{MS1}	Mechanical compliance component (TGM) model, Voigt branch
R_{MS2}	Mechanical resistance component (TGM) model, Maxwell branch
C_{MS2}	Mechanical compliance component (TGM) Model, Maxwell branch
S_C	Effective area of the cone excluding the dust cup
S_{DC}	Effective area of the dust cup
S_{SP}	Effective area of the spider
S_{DC}	Effective area of the dust cup
U_C	Frontal volume velocity of the cone
U_C^-	Rear volume velocity of the cone
U_D	Frontal volume velocity of the dust cup
U_D^-	Rear volume velocity of the dust cup
U_{SP}	Frontal volume velocity of the spider
U_{SP}^-	Rear volume velocity of the spider
P_C	Pressure generated by the cone excluding the dust cup
P_{DC}	Pressure generated by the dust cup
P_{SP}	Pressure generated by the spider
Z_{AFC}	Frontal acoustic radiation impedance of the cone excluding the dust cup
Z_{ARC}	Rear acoustic radiation impedance of the cone excluding the dust cup
Z_{AFD}	Frontal acoustic radiation impedance of the dust cup
Z_{AFS}	Frontal acoustic radiation impedance of the spider
Z_{ARV}	Acoustic radiation impedance of the center pole vent
M_{AV}	Acoustic mass of the center pole vent excluding the radiation impedance
C_{ADC}	Compliance define by the volume behind of the dust cup
Z_{ARV}	Radiation impedance of the vent
M_{AG1}	Acoustic mass of the annular slit generated by the cylindrical surface of the center pole and the inner surface of the voice coil former
R_{AG1}	Acoustic resistance associated to M_{AG1}
C_{AM}	Compliance due to the volume between the cylindrical surface and the center pole and the inner cylindrical surface of the magnet
M_{AG2}	Acoustic mass of the annular slit generated by the surface of the voice coil turns and internal cylindrical surface of the top plate.

[1] Truncated Generalized Maxwell Model.

R_{AG2} Acoustic resistance associated to M_{AG2}

3 Validation of the method

Suitable impedance tubes were built in order to be able to measure in the frequency range of interest, in order to verify if the set- up was measuring correctly, initially three measurements were performed; the impedance ratio frequency response of two separate Helmholtz resonators and then of both of them coupled. Figure 3 and 4 show respectively schemes of resonators R1, R2, and R1 coupled to R2, Table 1 shows the dimensions of the resonators. Figure 5 and 6 (a) and (b) show respectively the measured magnitudes of the acoustic impedance of resonators R1 and R2 superimposed to the calculated magnitudes solving the equivalent circuits shown in part (b) of this figures.

Figure 7 (a) and (b) shows superimposed the comparison between measured acoustical impedance and the calculated magnitude solving the circuit shown in part (b) for the case of R1 coupled to R2, the effect of coupled mases was included due to the fact that the neck openings were very close and facing each other inside the first volume [4] good agreement was found between measured and calculated values. Figure 8 show a picture of this last measurement. In order to verify that the effect of filling material could be accurately measured, an additional measurement was performed adding filling material to R1. Figure 9 (a) and (b) show the comparison between measurements done with and without filling material. The elements of the circuits were calculated mainly with the well-known formulas presented in [5].

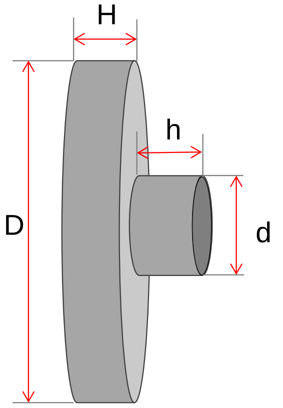


Figure 3. Scheme of resonator R1 and R2.

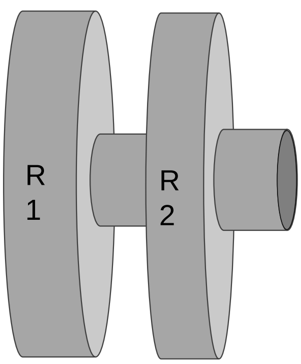
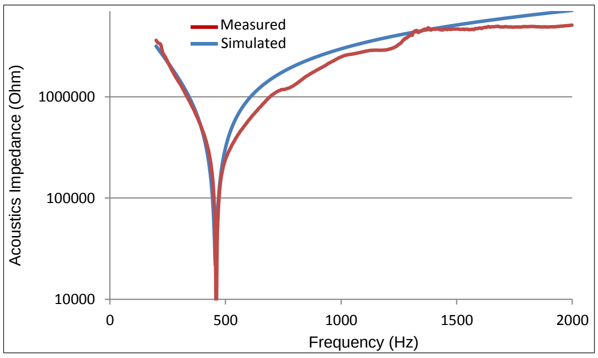


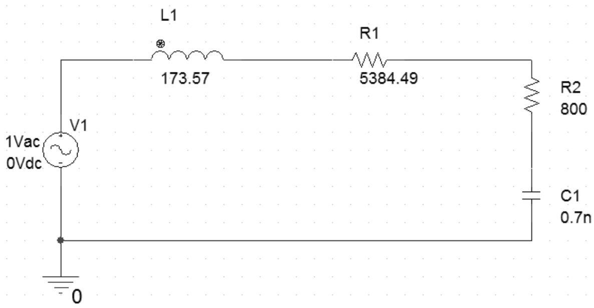
Figure 4. Scheme of resonator R1 coupled to R2

Table 1. Dimensions of R1 and R2.

Dim [m]	R2	R1
H	0.0202	0.012
D	0.082	0.1012
h	0.0396	0.028
d	0.021	0.021

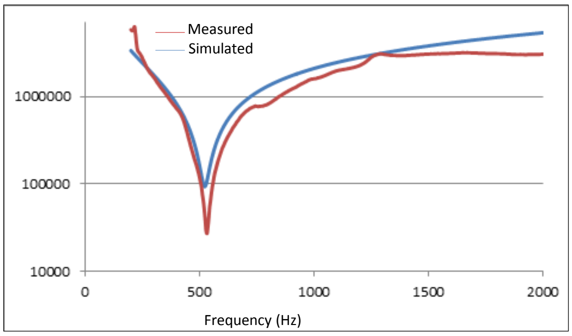


(a)

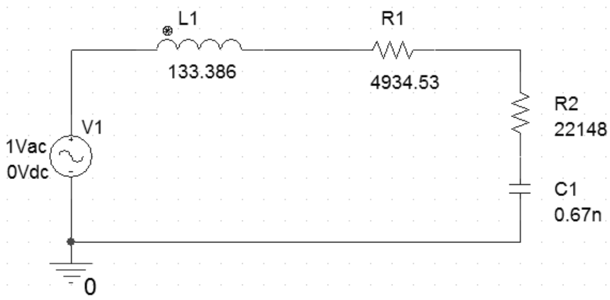


(b)

Figure 5. Measured and simulated impedance (a) and equivalent circuit for resonator R1 (b).

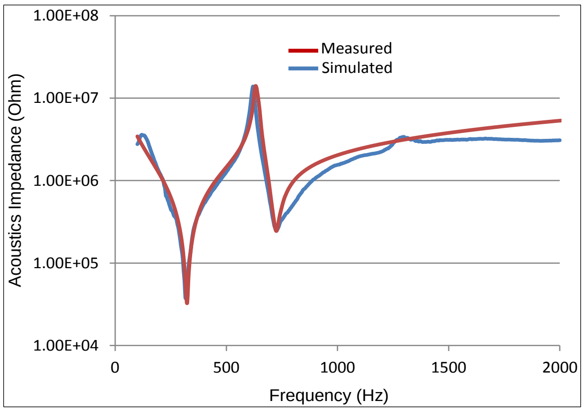


(a)

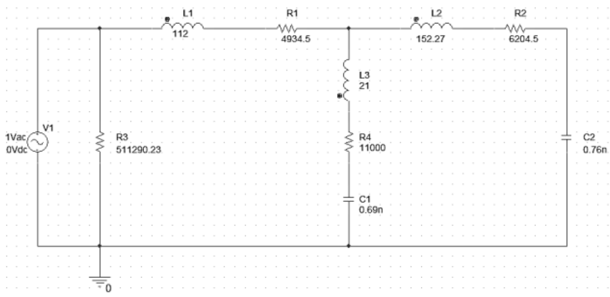


(b)

Figure 6. Measured and simulated impedance of R2 (a). Equivalent electric circuit representing R2 (b).



(a)



(b)

Figure 7. Measured and simulated magnitude of the acoustic impedance for R1 coupled to R2.(a) Equivalent electric circuit representing resonator R1 coupled to R2. (b)

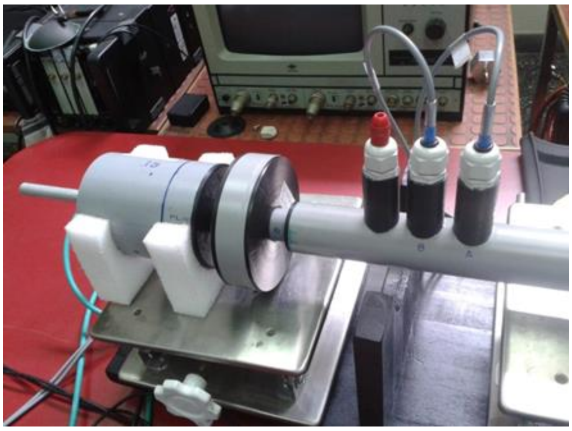
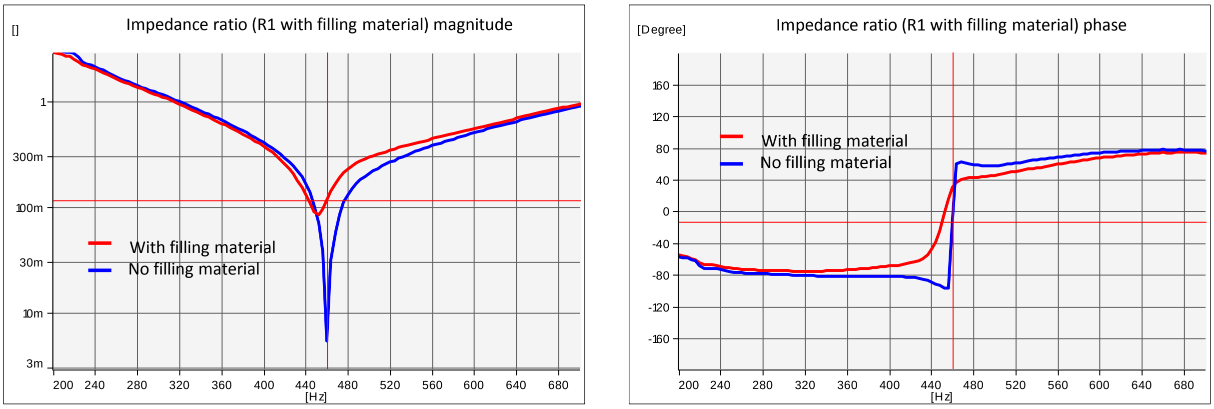


Figure 8. Measurement of coupled resonator.

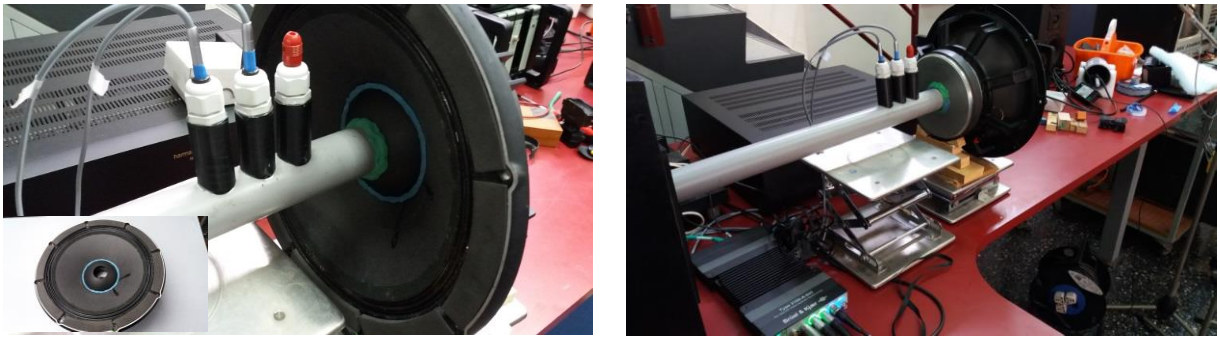


(a) (b)

Figure 9. Resonator R1 measured impedance ratio magnitude with and without filling material (a). Impedance ratio phase with and without filling material (b)

4 Measurement of a loudspeaker

A 12” inch loudspeaker with a magnetic circuit similar to the one shown in Figure 1 was measured under two different conditions, first the end of the impedance tube was placed in a hole cut in the dust cup, then a second measurement was done with the end of the impedance tube placed in the opening of the vent in the back yoke of the loudspeaker; Figure 10 (a) and (b) show respectively these two measurements.

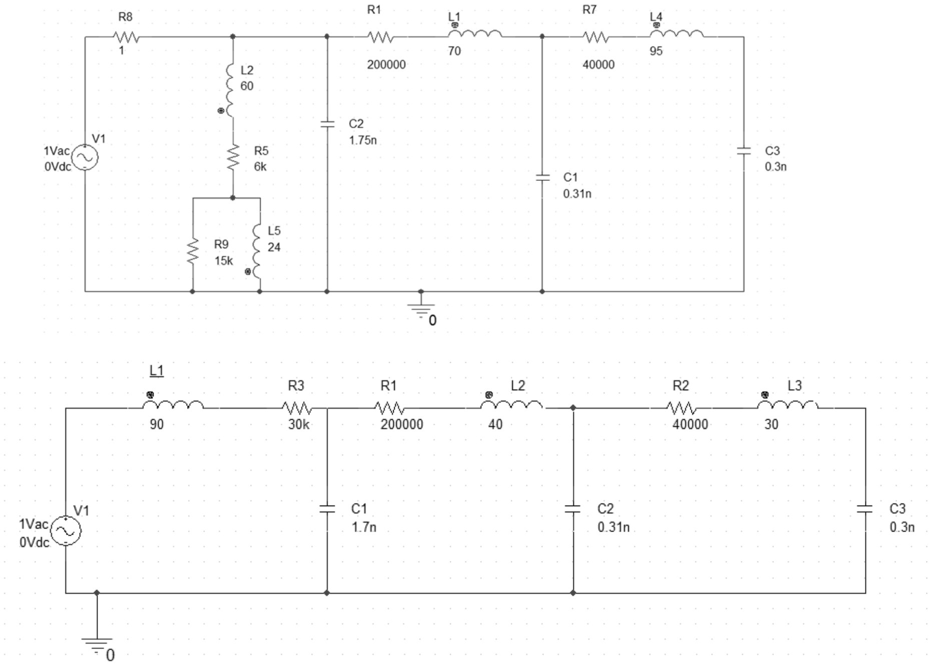


(a) (b)

Figure 10. Pictures of two measurements performed.

The equivalent electric circuits that represent these two cases are shown respectively in Fig. 11 (a) and (b), were the source due to the spider has been neglected in this approximation due to the fact the loudspeaker is not operating. Fig. 12 (a) and (b) show the measured magnitude superimposed to the simulated ones, a reasonable agreement was found between both results.

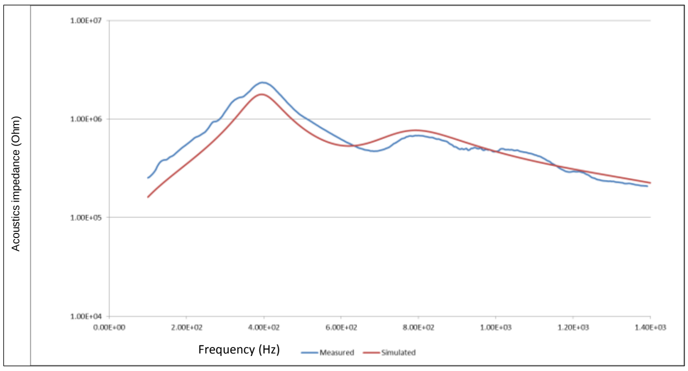
In order to be able to modify the loudspeaker, the dust cup was fixed with a kind of play dough, this made the border conditions of the dust cup more elastic than normal.



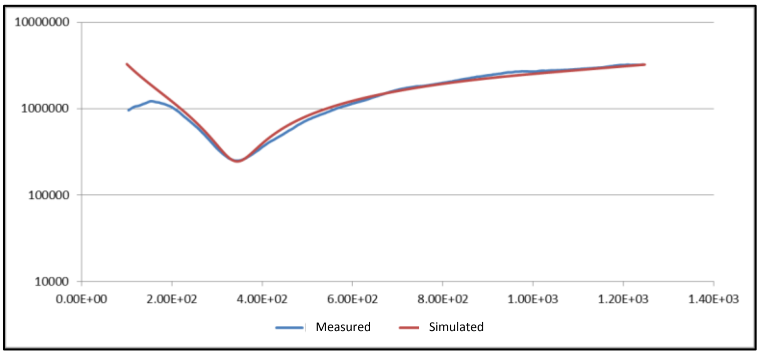
(a)

(b)

Figure 11. Electric equivalent circuits representing the acoustic impedance measurements with the impedance tube placed in the dust cup (a) and the impedance tube placed in the opening of the vent in the back yoke (b).



(a)



(b)

Figure 12. Superimposed acoustic impedance measured and calculated for the cases this described in figure 11.

5 Effect of filling material in the magnetic circuit

Fig. 13 and 14 shows respectively the comparison of the measured impedance ratio magnitude measured with different amounts of filling material compared to the case without filling material when the measurements are performed through the hole in the dust cup and through the vent in the rear yoke. The effect of the added material can clearly be seen. Peaks and deeps are opposite in both figures. In figure 13 the first resonance was measured through a high pressure opening in the dust cup, in figure 14 the first resonance was measured through a low pressure opening.

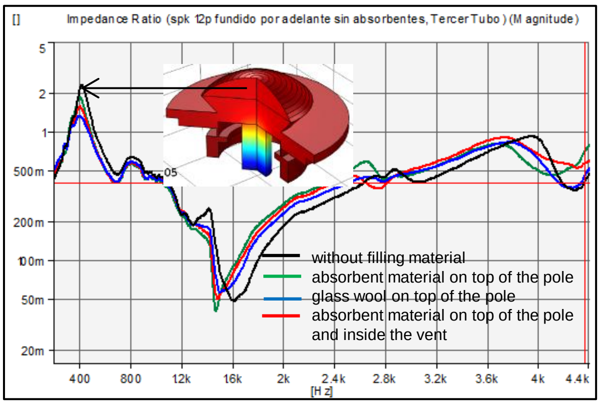


Figure 13. Magnitude of the impedance ratio measured with different amounts of filling material when the measurements are performed through a hole in the dust cup

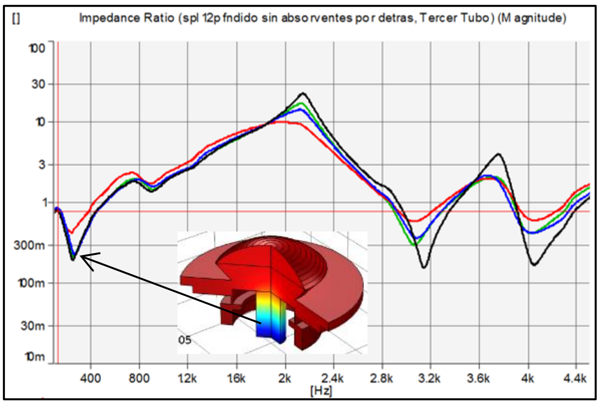


Figure 14. Magnitude of the impedance ratio measured with different amounts of filling material when the measurements are performed through the vent in the rear yoke

Measuring set up

Figure 15, show the measuring setup

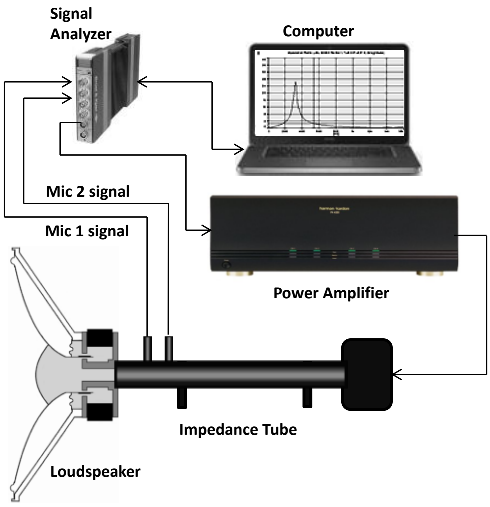


Figure 15. Measuring setup.

Instrumentation	Type
Signal Analyzer	B&K 3160-B-042
Power Amplifier	Harman Kardon PA 2000
Impedance Tube	Custom Made
Microphones	B&K 4187 + 2670

7 Conclusions

1. It is possible to measure the acoustic impedance of the cavities, ducts and combination of these elements within the magnetic circuit of a loudspeaker.

2. It is possible to measure the effect of filling material or other type of acoustic resistance added to the cavities of the magnetic circuit, therefore materials can be compared and so the effect of these can be optimized
3. Smaller transducers than the one measured in this paper could be measured if the correct impedance tube is available.

8 Acknowledgments

We want to thank Alfredo Koc Lee for his help with some of the calculations and Paul Castro Johanson for his help in the measurements.

9 References

[1] Shozo Kinoshita.; Bart Locanthi. The influence of parasitic resonances on compression driver loudspeaker performance. *AES preprint No 1422 (M-2) 61st Convention November 3-6*.

[2] Rene Boonen.; Paul Sas.; Erick Van den Bulk. Acoustic damping of an annular tail pipe under mean flow condition. *Euro Noise 2015 31 May-3 June Maastricht*

[3] Masateru Kimura.;Jason Kunio.; Andreas Schuhmacher.;Yunseon Ryu. A new high frequency impedance tube for measuring sound absorption coefficient and sound transmission loss. *Internoise 2014*

[4] Torbörn A. Johanson.; Mendel Kleiner; Theory and experiments on the coupling of two Helmholtz resonators. J. Acoust. Soc. 110 (3) sep 2001, pp 1315-1328.

[5] Beranek, L.L. *Acoustics*, Mc Graw Hill, (USA), 1954