



Dyson School
of Design
Engineering

ESTIMATING EAR CANAL VOLUME THROUGH ELECTRICAL IMPEDANCE MEASUREMENTS FROM IN-EAR HEADPHONES – INITIAL RESULTS

Imperial College
London

Marco Comunità, Lorenzo Picinali
m.comunita@imperial.ac.uk

A close-up profile photograph of a woman with dark hair tied back, wearing a white earbud. A semi-transparent grey box is overlaid on the lower part of the image, containing text and a double-headed arrow. The background is dark with several out-of-focus, warm-toned circular lights.

**EAR CANAL
ACOUSTICS**

**ELECTRICAL
IMPEDANCE**

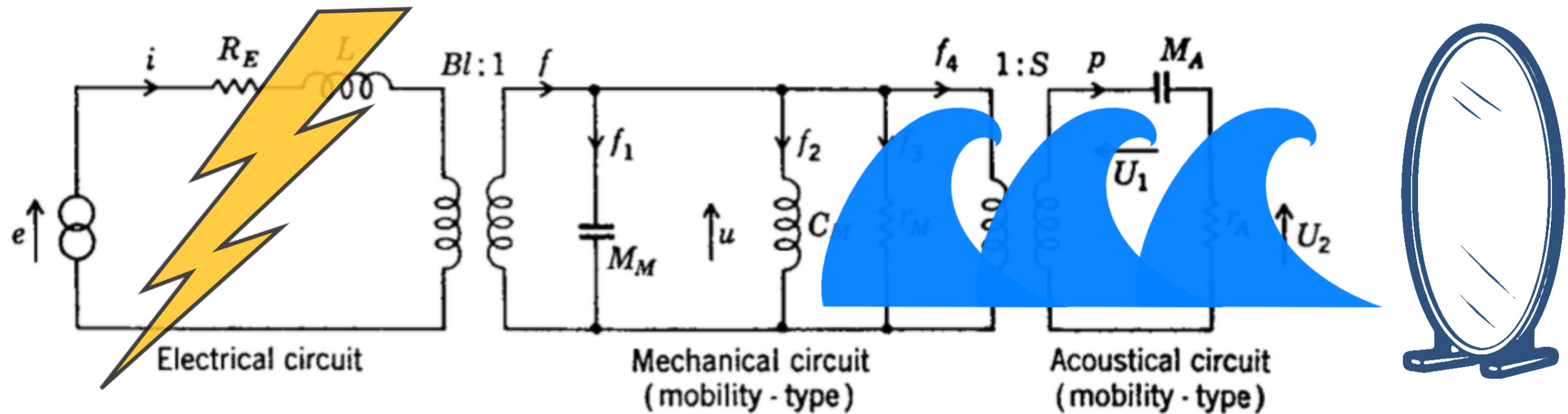


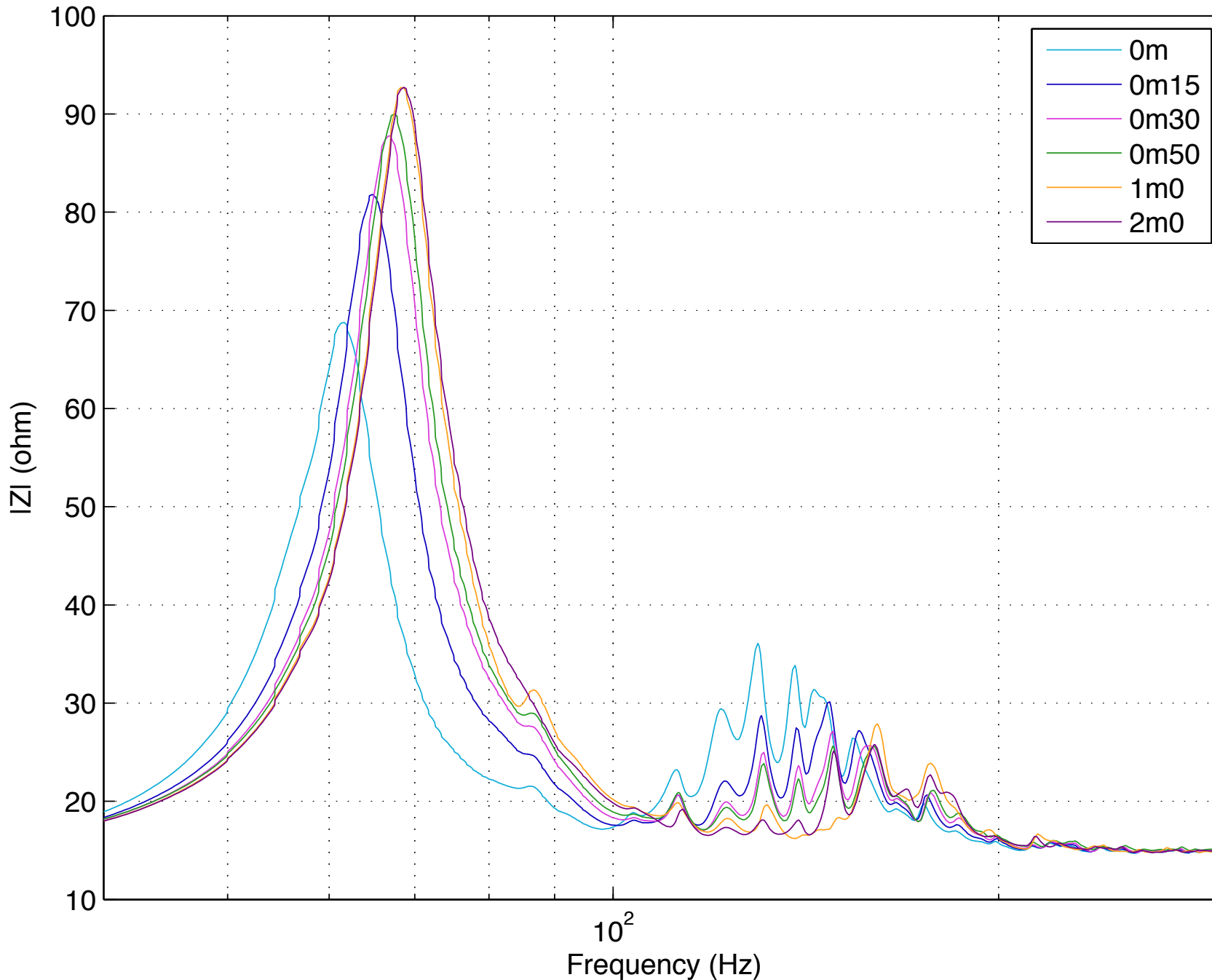
SHORT-TERM GOALS

- Verify impact of ear canal on headphones' electrical impedance is measurable
- Investigate influence of dimensions of ear canal simulators on electrical impedance
- Establish a relation between electrical impedance and pressure at the "eardrum"



Blackstar[®]
AMPLIFICATION





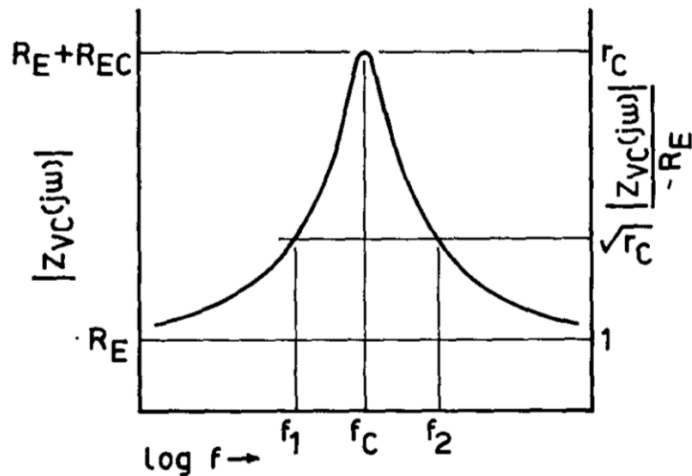
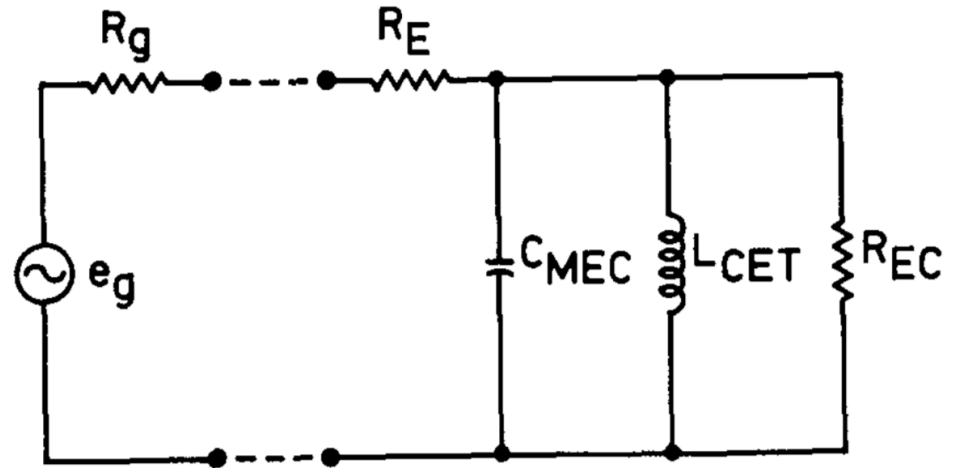
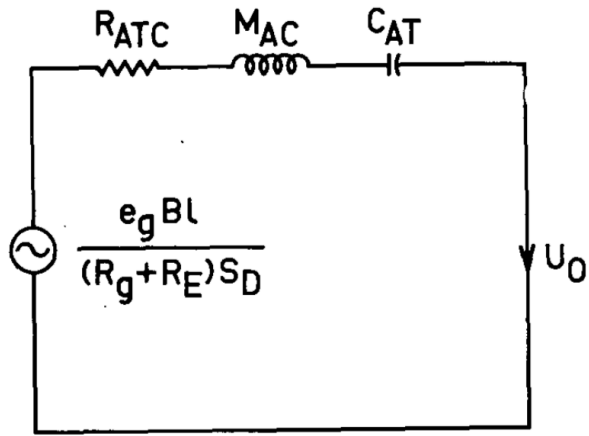
Influence of Placement on Loudspeakers' Electrical Impedance

Submitted by:
Marco Comunità

Supervised by:
Dr. Joshua D. Reiss



THEORY

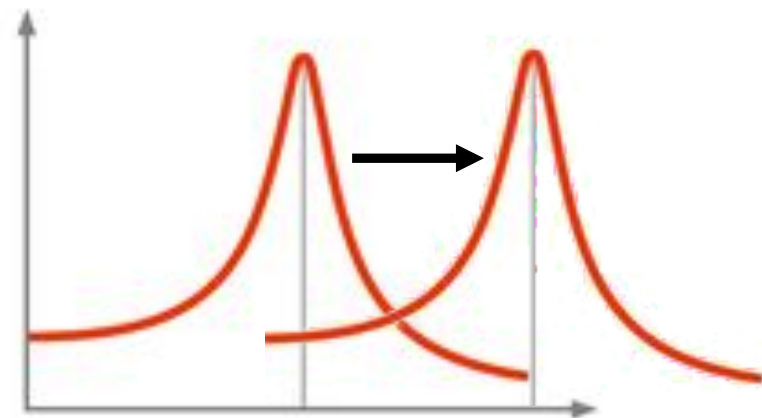
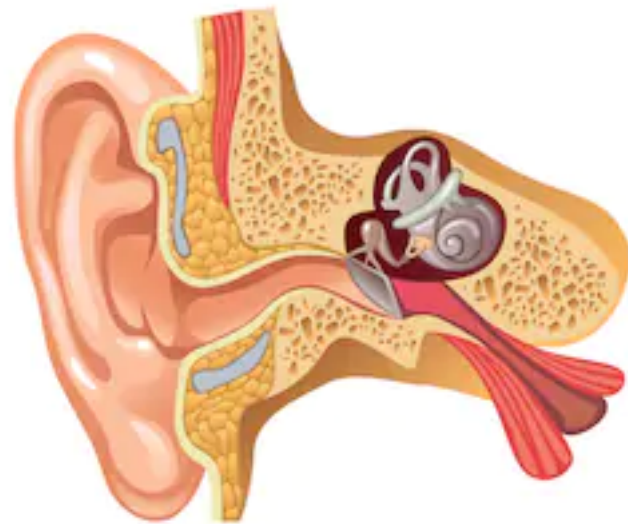


Driver Suspension & Enclosure Compliance

$$\frac{1}{\omega_C^2} = C_{AT} M_{AC} = C_{MEC} L_{CET}$$

$$V_{AT} = \rho_0 c^2 C_{AT}$$

Driver and Air Load Mass



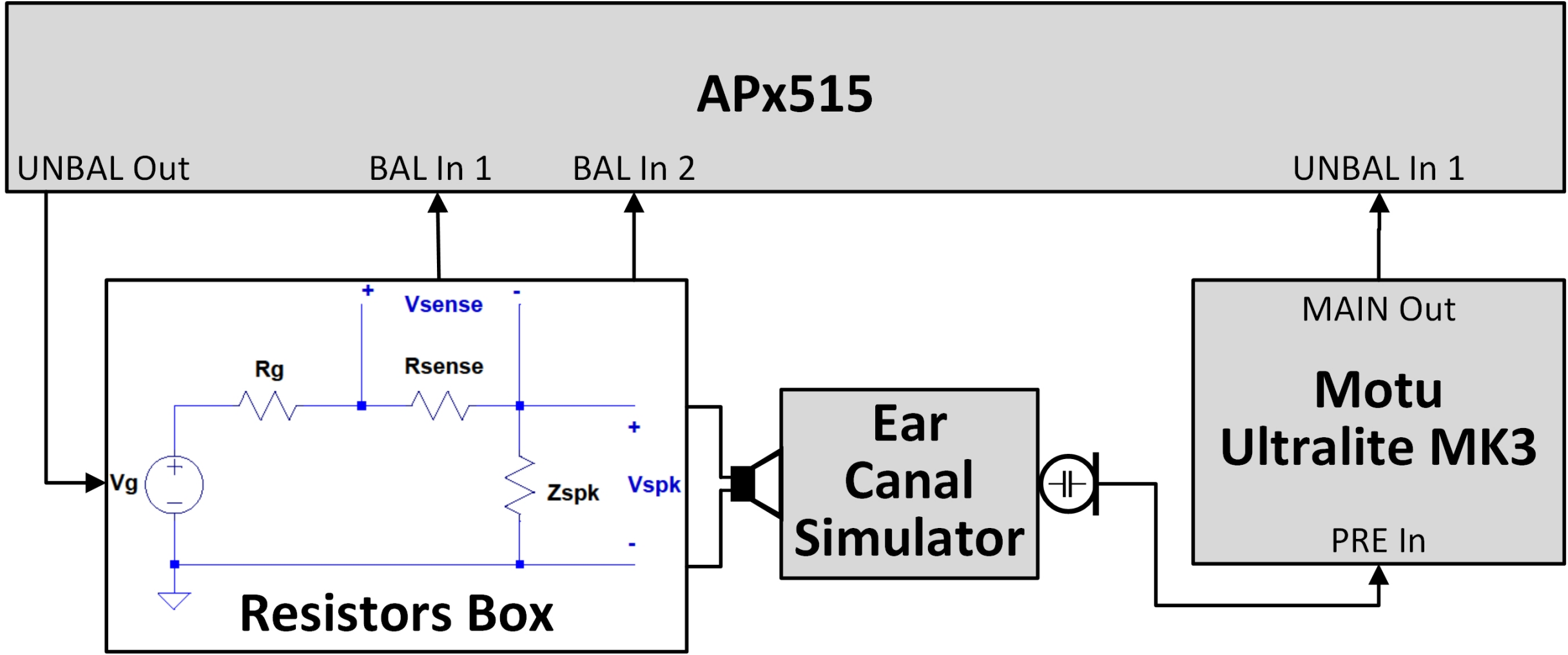


MEASUREMENTS



EAR CANAL SIMULATORS

- CONSTANT VOLUME (variable length & diameter)
- CONSTANT DIAMETER (variable volume & length)



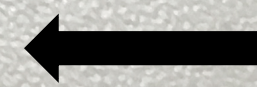
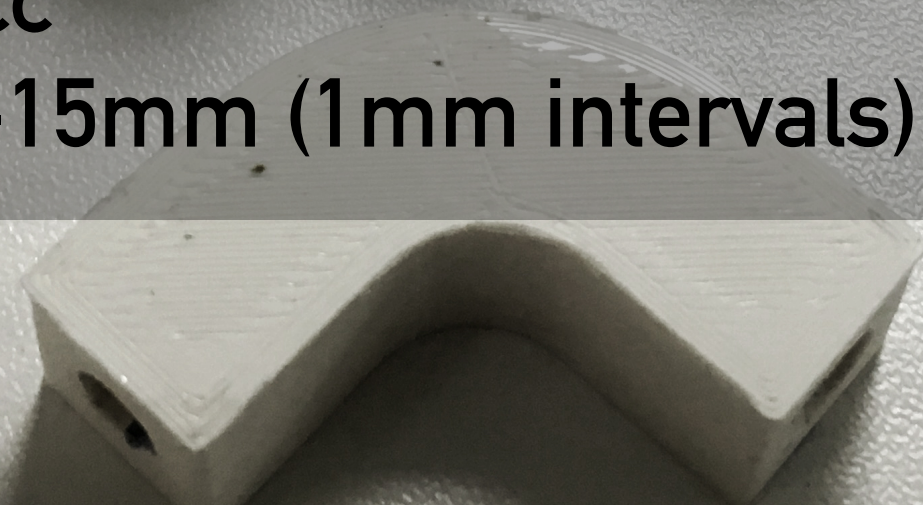


CONSTANT VOLUME

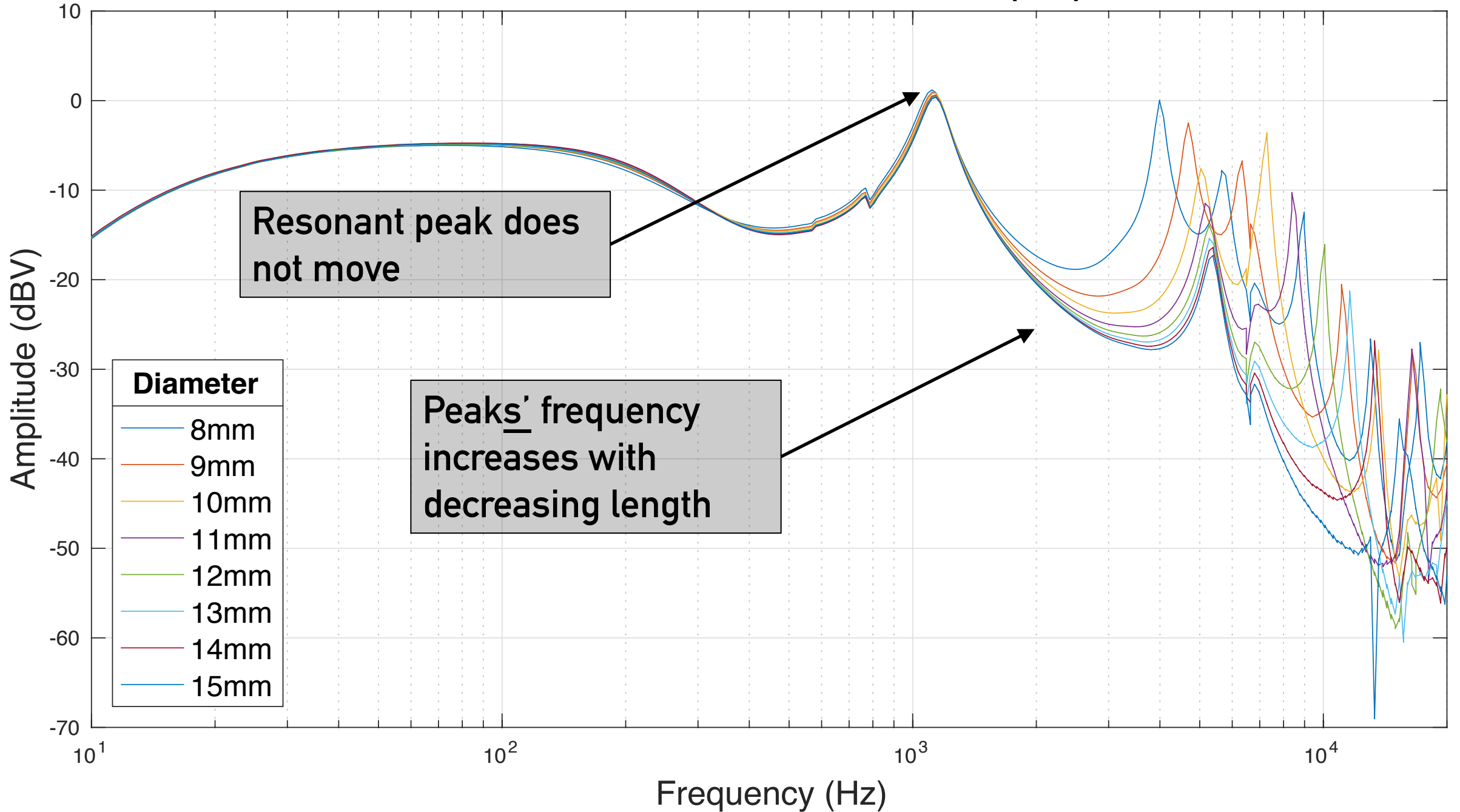


VOLUME
DIAMETER

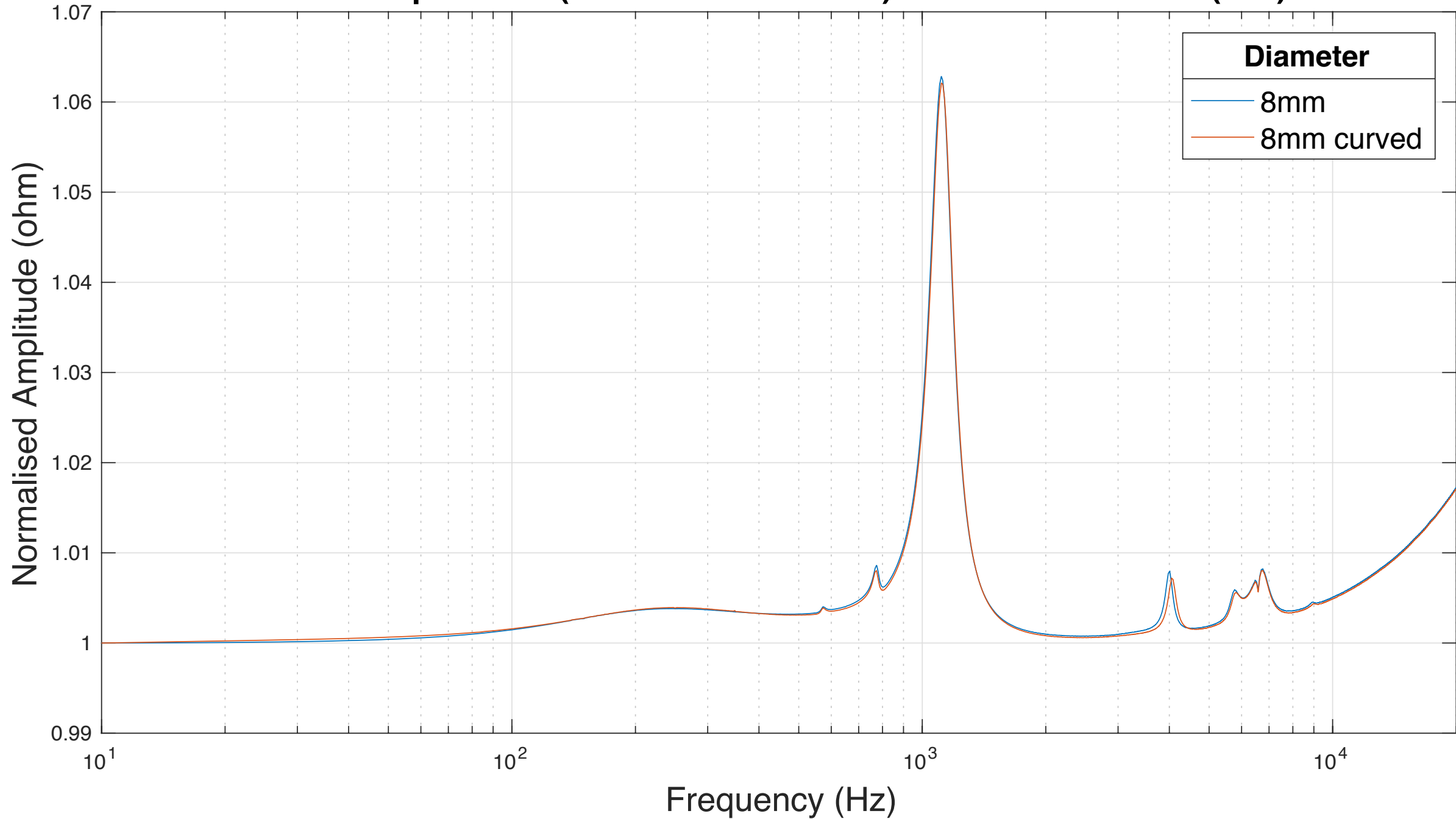
2cc
8-15mm (1mm intervals)



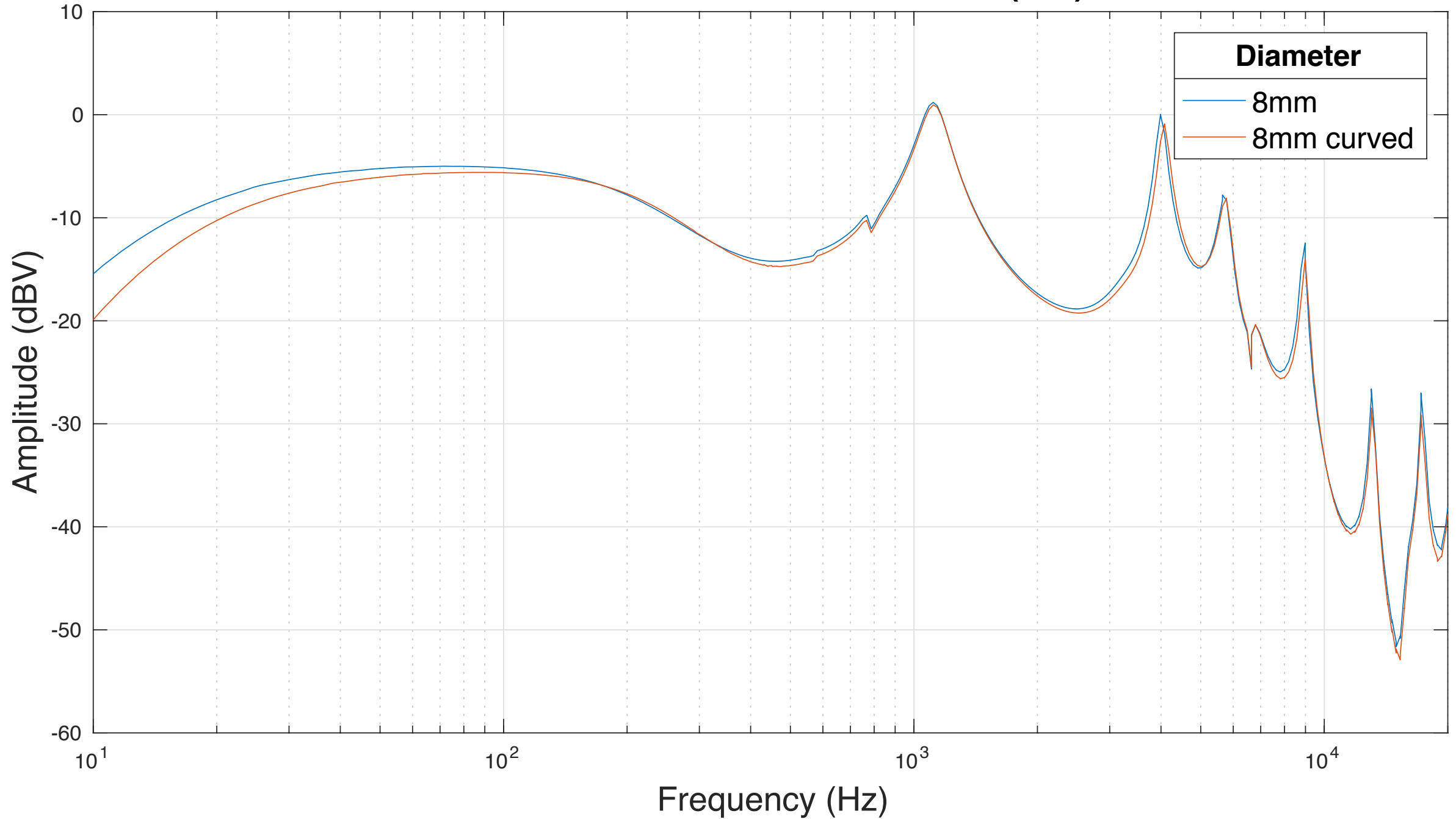
Mean Pressure - Constant Volume (2cc)



Mean Impedance (Normalised @ 10Hz) - Constant Volume (2cc)



Mean Pressure - Constant Volume (2cc)





CONSTANT DIAMETER

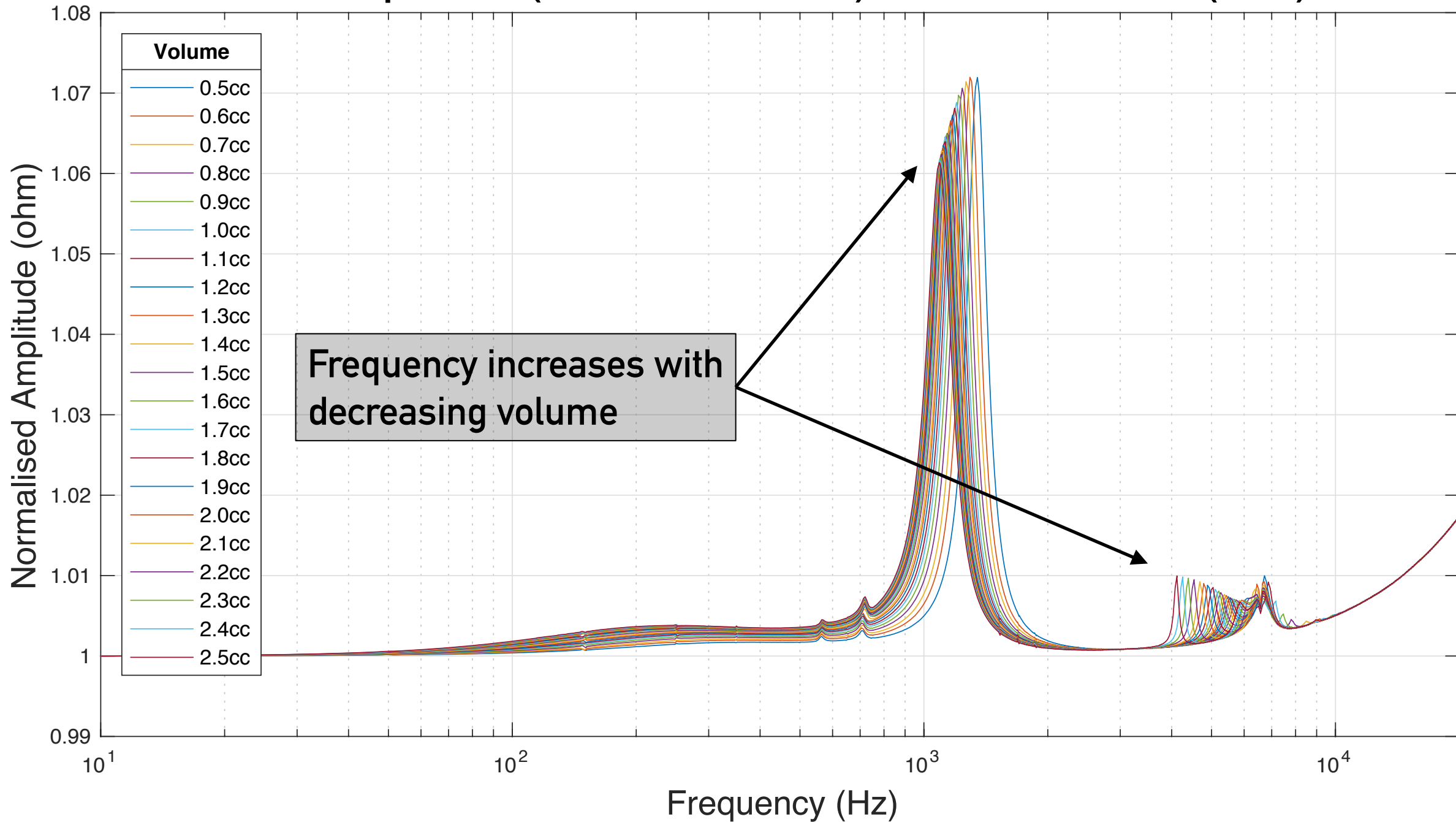
VOLUME
DIAMETER

0.5-2.5cc (0.1 cc intervals)
8.5mm

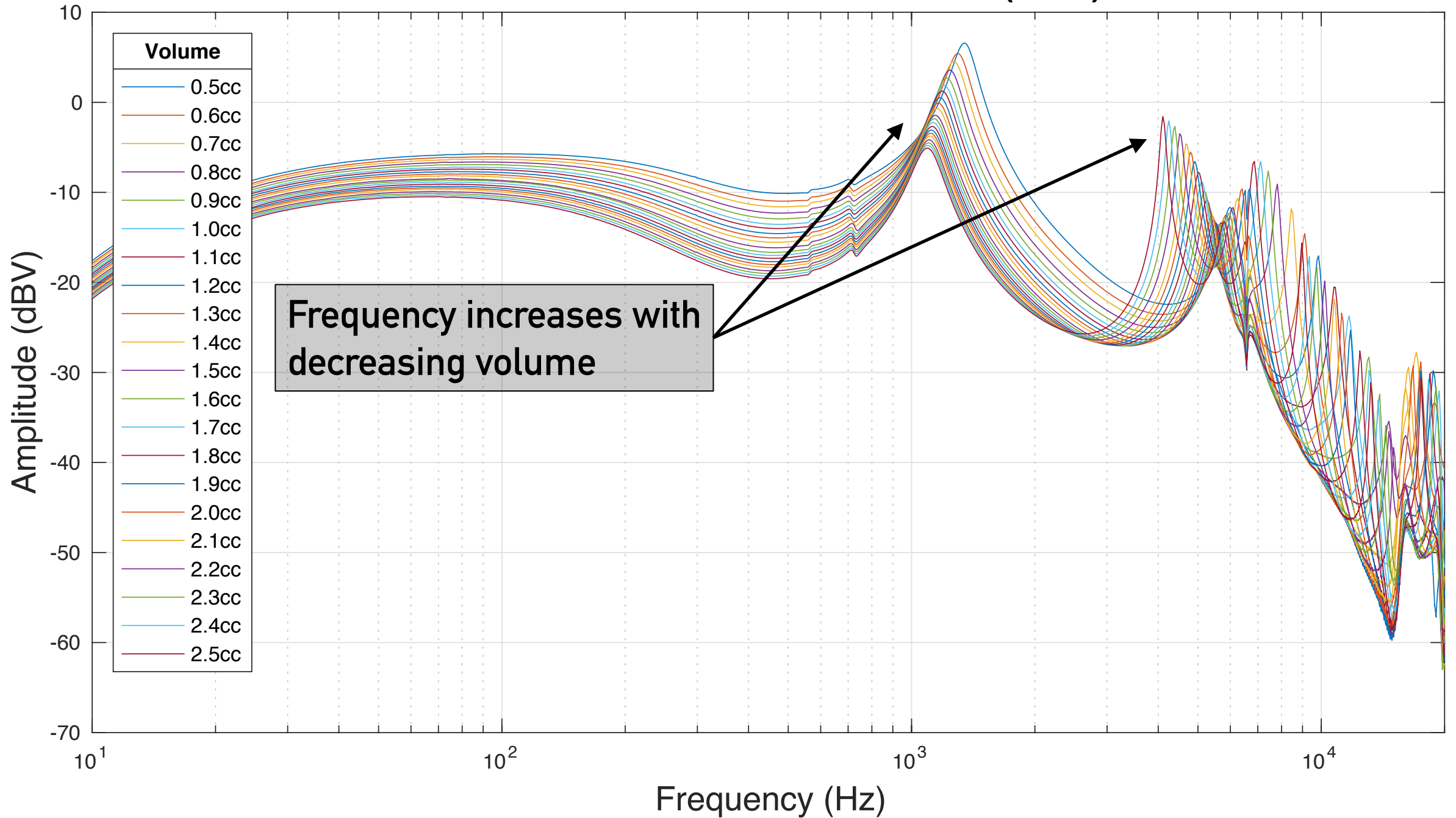


INFANTS	0.4-1.0cc
ADULTS	0.6-2.5cc
-	
DIAMETER	6.5-8.5mm

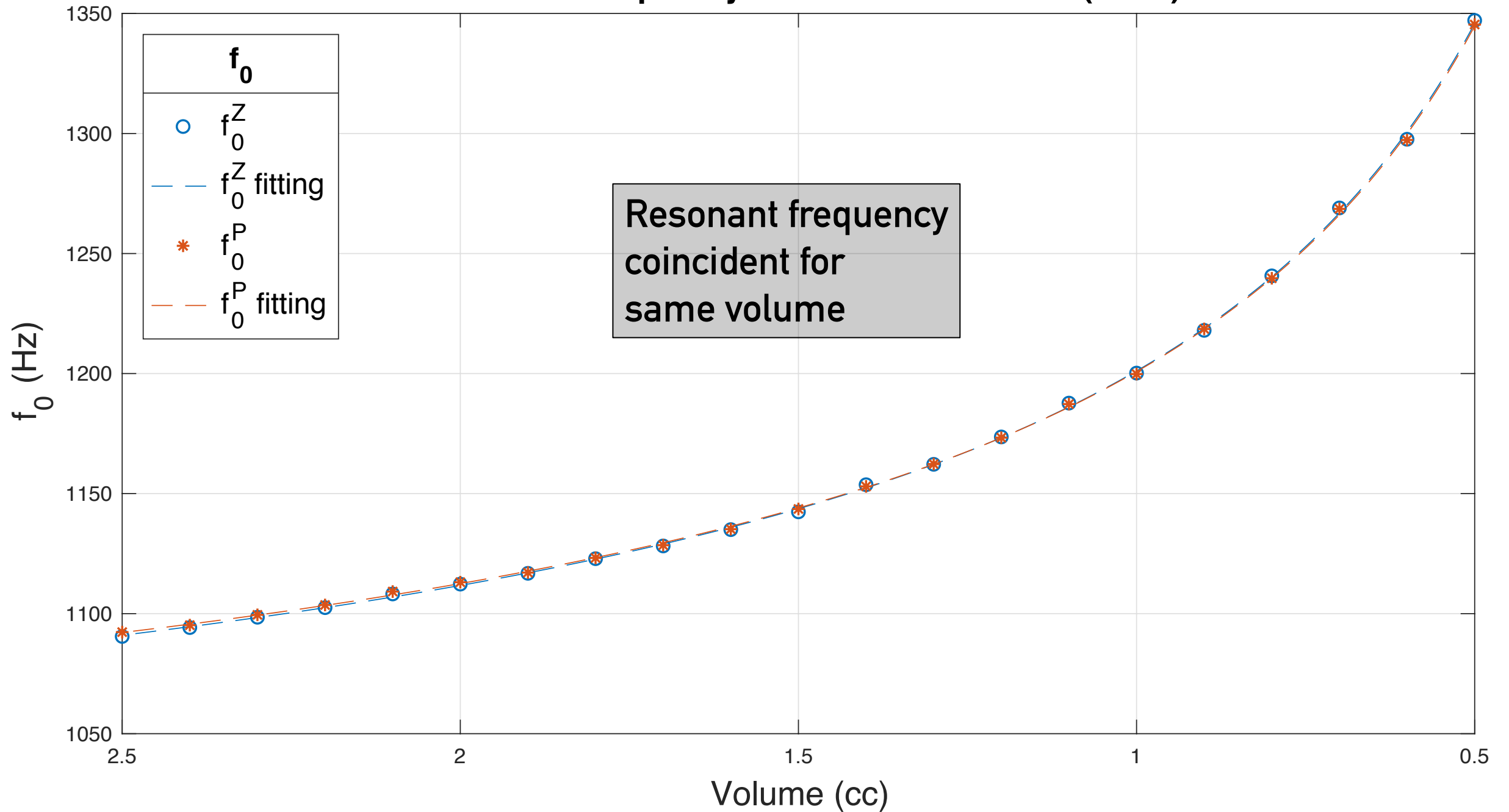
Mean Impedance (Normalised @ 10Hz) - Constant Diameter (8mm)



Mean Pressure - Constant Diameter (8mm)



Resonant Frequency - Constant Diameter (8mm)





CONCLUSIONS



SHORT-TERM GOALS

- Ear canal impact on headphones' electrical impedance is measurable
- Ear canal dimensions affect the electrical impedance
- Relation between electrical impedance and pressure at the “eardrum”

NEXT STEPS

- Calculate the ear canal volume based on impedance measurements using Thiele-Small parameters
- Compare the results with the estimations obtained with a tympanometer

LONG-TERM GOALS

- Extract information about ear canal dimensions and pressure at the eardrum from electrical impedance measurements
- Extend the work to different types of headphones and human subjects



APPLICATIONS



- Exploit the knowledge for diagnostics and leisure purposes
- Detect potentially harmful listening habits
- Headphones design
- Sound personalisation

The logo for the Dyson School of Design Engineering features a series of white diagonal lines on a black background, creating a stylized 'D' shape. The text 'Dyson School of Design Engineering' is overlaid on the right side of this graphic.

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THANK YOU!

**Imperial College
London**

Marco Comunità, Lorenzo Picinali
m.comunita@imperial.ac.uk