EXPERIMENTAL INVESTIGATION OF ACOUSTIC PROPERTIES OF 3D VOCAL AND NASAL TRACTS WITH YIELDING WALLS - PRELIMINARY STUDY

Vojtěch Radolf*, Jaromír Horáček*, Jan Košina*
Tomáš Vampola**

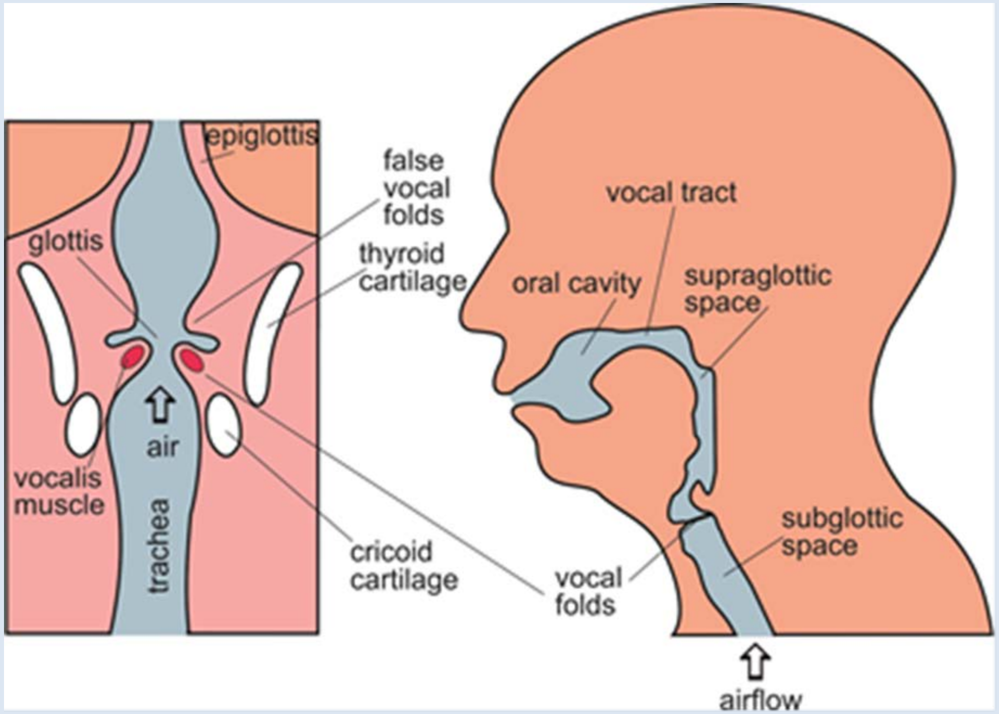
*Institute of Thermomechanics, Academy of Sciences, Prague, Czech Republic
**Faculty of Mechanical Engineering, Czech Technical University in Prague

INTRODUCTION

Human voice - produced by self-oscillating vocal folds (VF) excited by air flowing from the lungs.

VF vibration - modulates the stream of air generating the primary sound.

This sound propagates inside the supraglottal cavities (i.e., in the vocal tract - VT) which modify its quality.

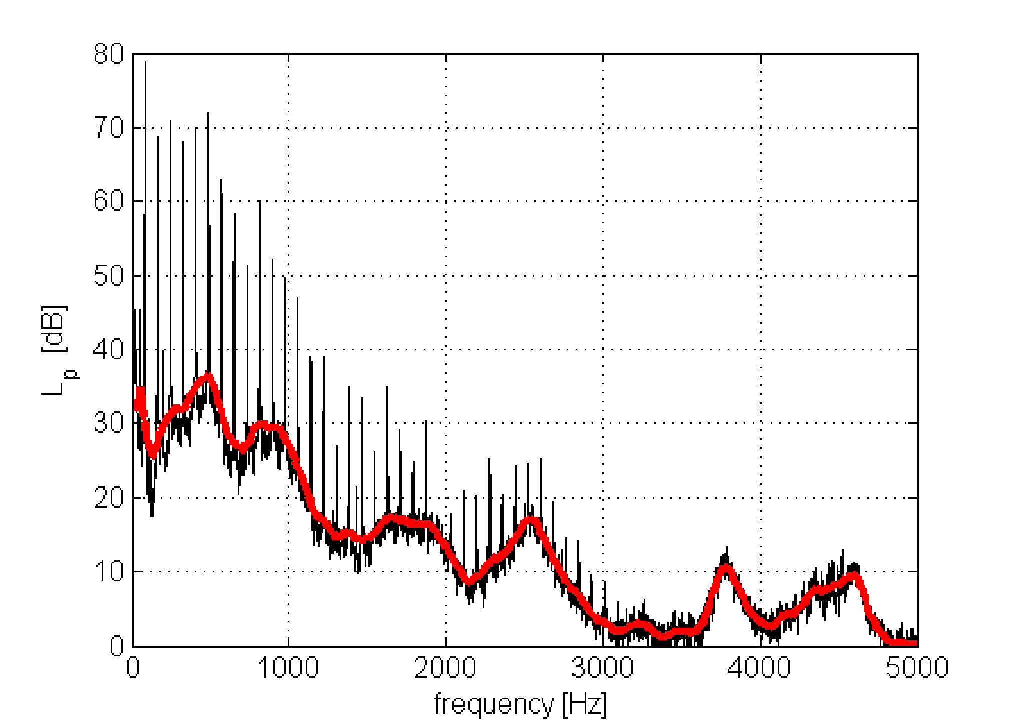


INTRODUCTION

Acoustic resonances of VT
 – create so-called formants - peaks in the envelope of the voice spectrum.

Formants define vowels and the voice timbre.

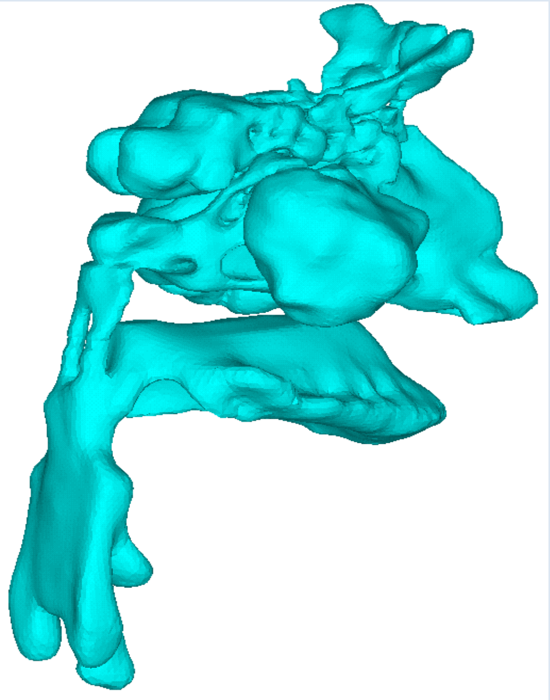
Final sound quality - given both by characteristics of VF vibration and by VT properties, see e.g. [1].



[1] Sundberg J.: The science of the singing voice, DeKalb, Illinois: N. Illinois Univ. Press, 1987.

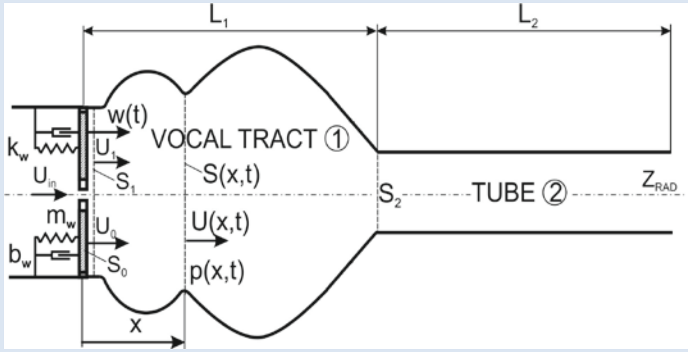
INTRODUCTION

Nowadays - 3D models - complex structure of VT, including the nasal cavities.



However, less is known about the influence of soft tissue on the resulting sound .

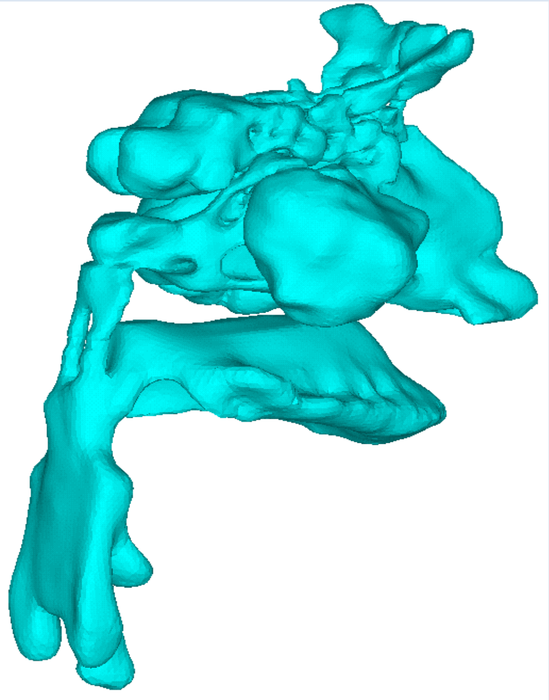
Compliance of the soft tissues of VT
- influence freq. and amplitude of formants
  - mainly the lowest formant frequencies [2].



[2] Radolf V., Horáček J., Dlask P., Otčenášek Z., Geneid A., Laukkanen A.M.: Measurement and mathematical simulation of acoustic characteristics of an artificially lengthened vocal tract. Journal of Sound and Vibration 366, 2016, 556-570.

METHODS

3D VT model created from the CT measurement of a female subject during phonation [a:], see [3].



Rigid VT model: VeroCyan, E = 2-3 GPa

Soft VT model: VeroCyan + Agilus30Clear
Shore A hardness = 50

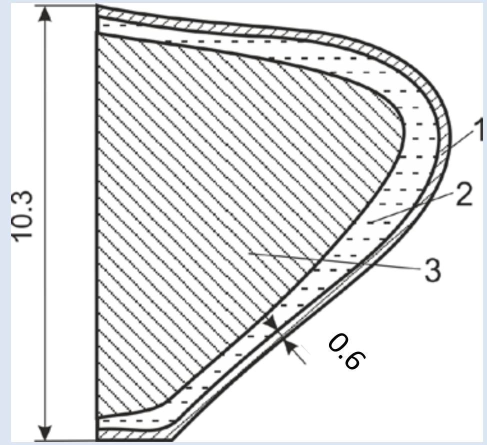
[3] Vampola, T., Horáček, J.,. Švec, J.G. (2015) Modeling the influence of piriform sinuses and valleculae on the vocal tract resonances and antiresonances, Acta Acustica United With Acustica, vol. 101, pp. 594-602.

METHODS

Measurements performed with a 1:1 scaled three-layer vocal folds (VF) model.

VF excited by airflow coming through the subglottal space (lungs).

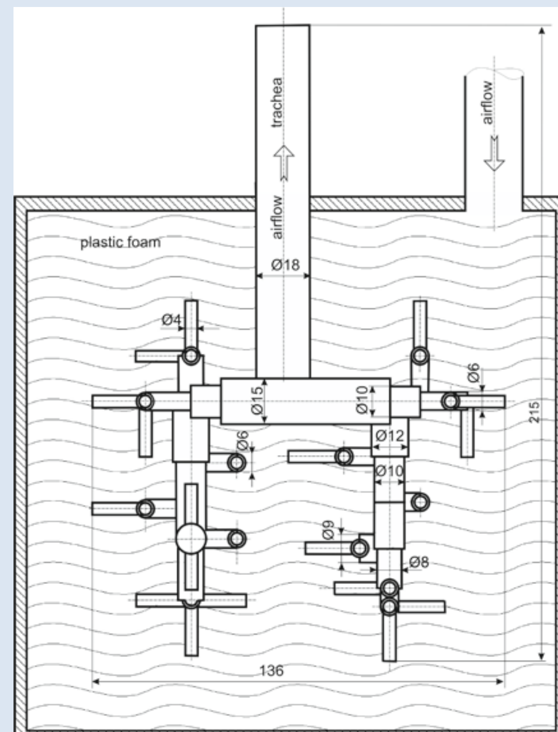
Airflow rate Q = 0.35 l/s
→ self-oscillations of VF (102 - 110 Hz).



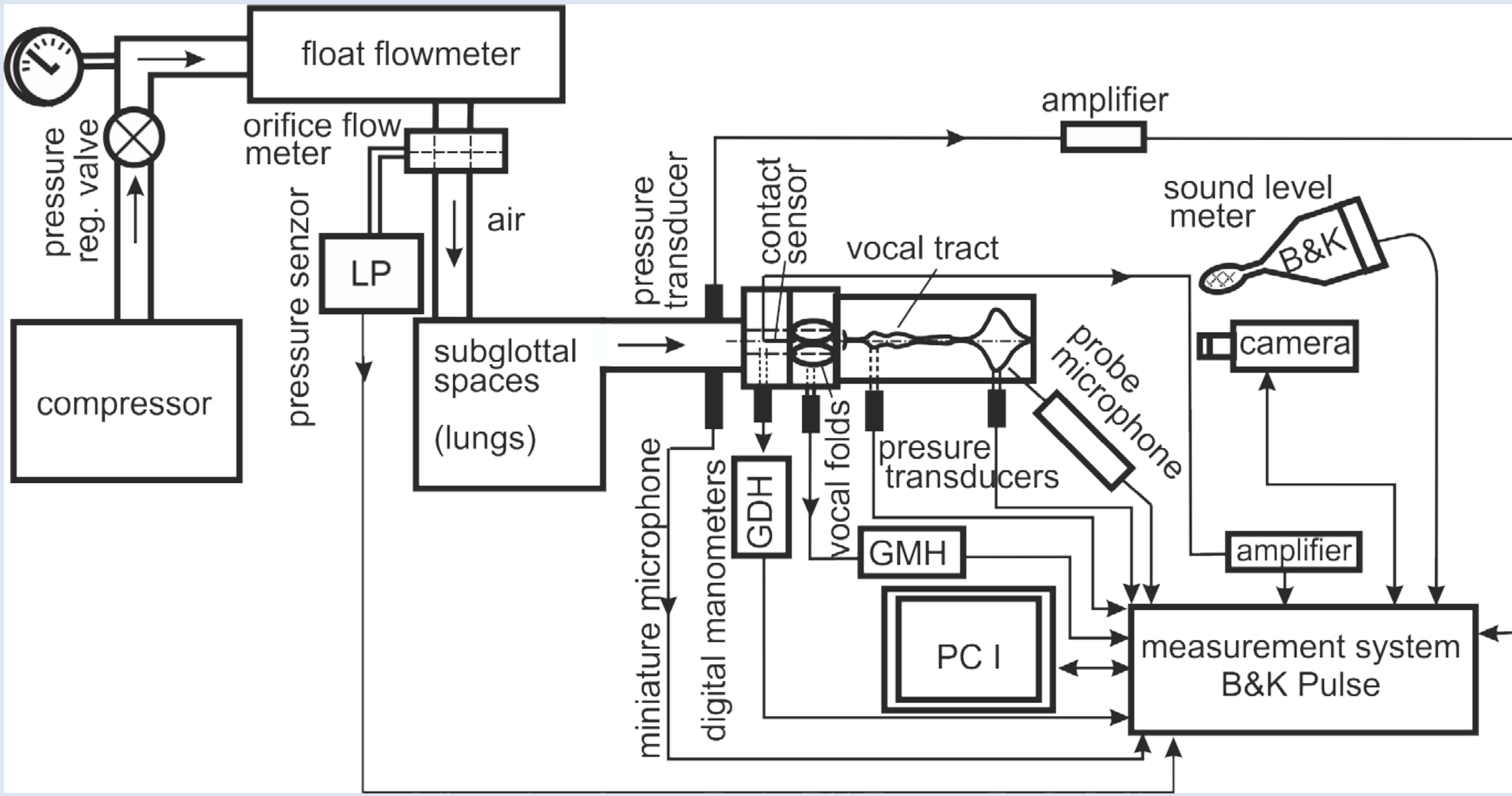
Silicon rubber cover

Liquid layer (lamina propria)

Silicon rubber wedge (vocal fold body)



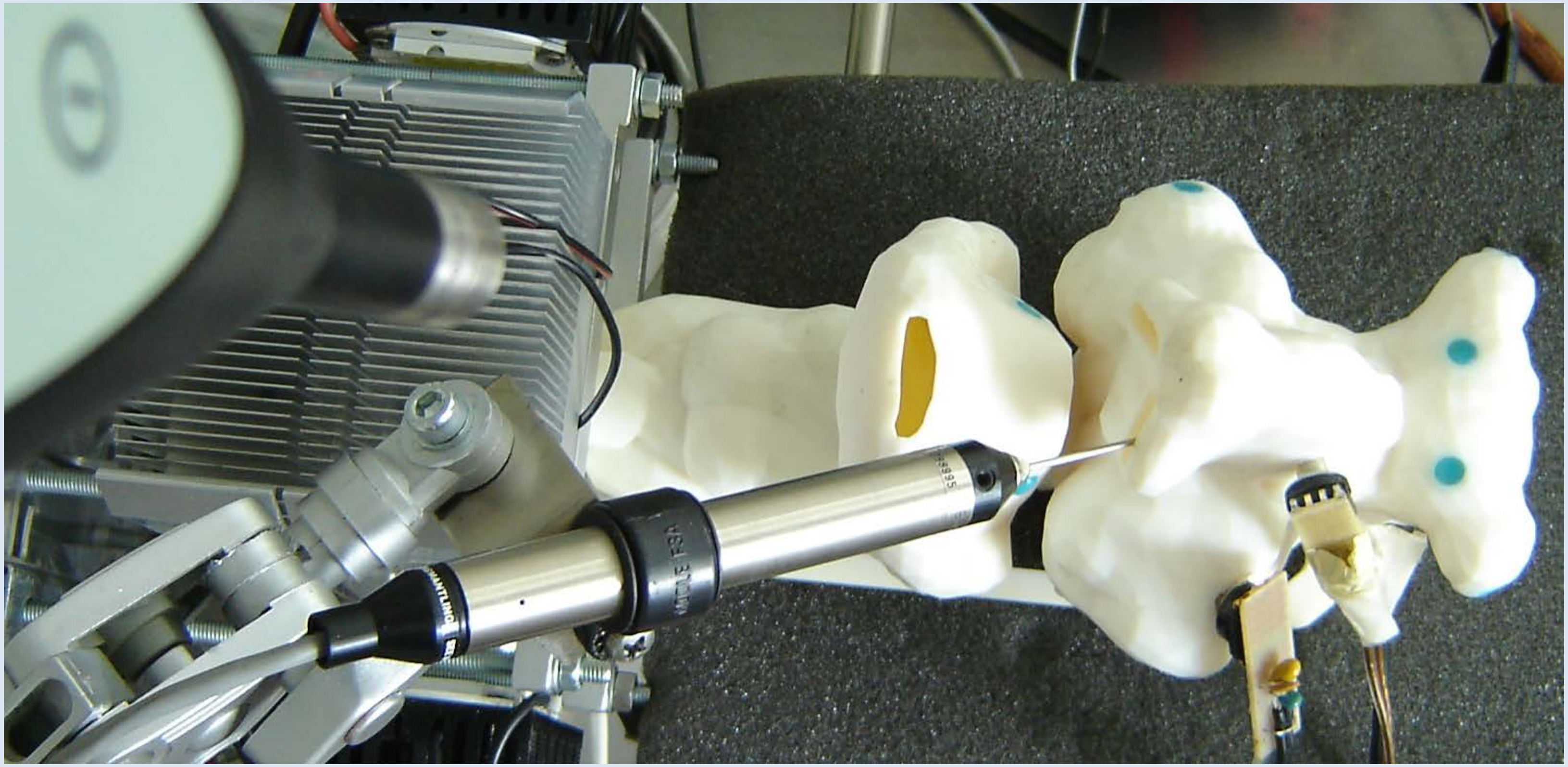
SCHEMA OF THE MEASUREMENT SET UP



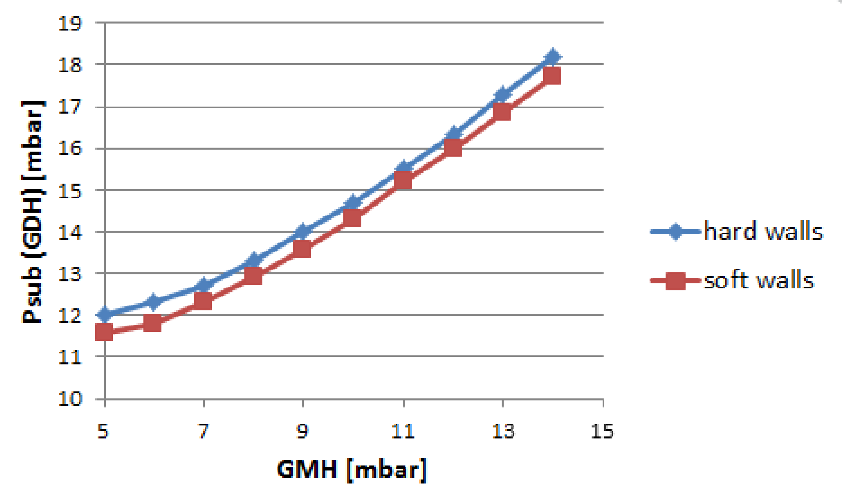
MEASUREMENT SET UP

Excitation by the self-oscillating vocal folds model

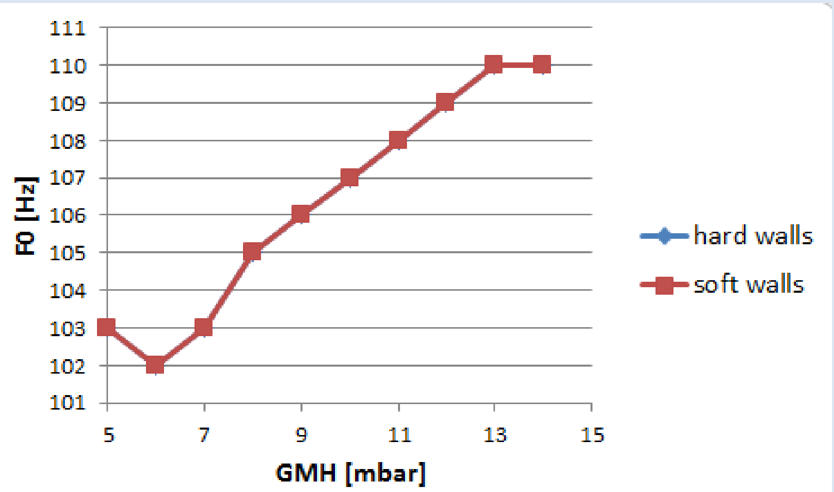
- subglottal pressure measured by dynamic semiconductor pressure transducer
- the sound level meter B&K 2239 installed 20 cm from the mouth
- signals simultaneously sampled by 16.384 kHz



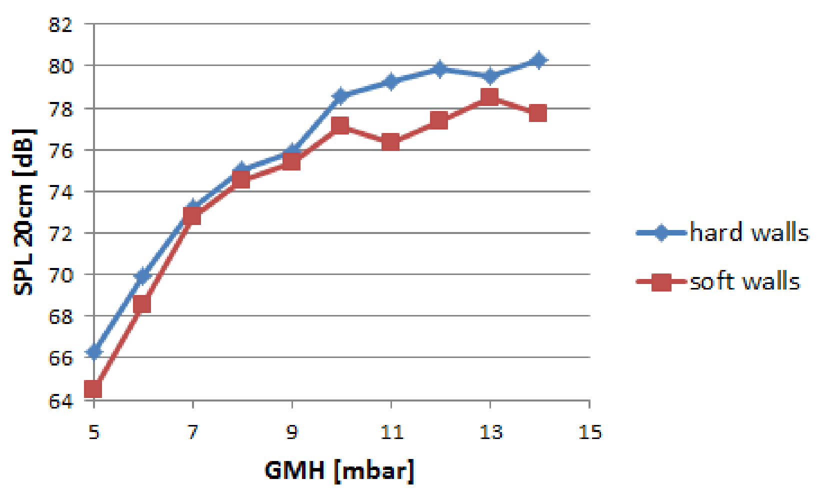
RESULTS



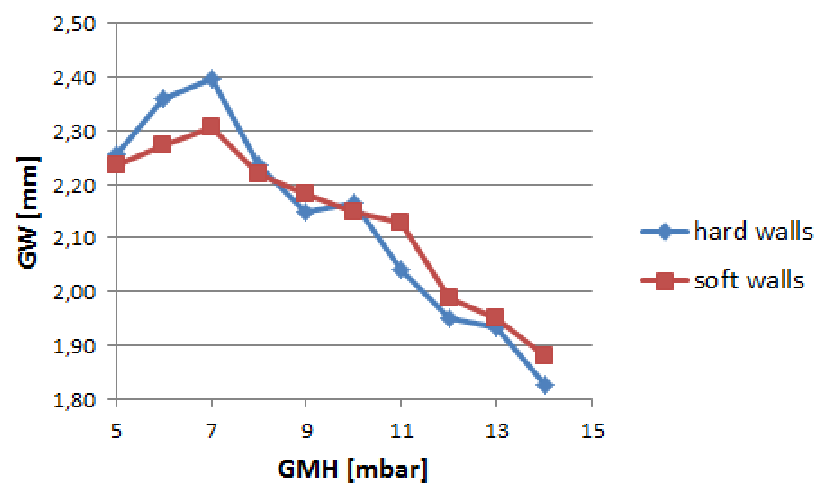
Psub (GDH) [mbar]
19
18
17
16
15
14
13
12
11
10
5
7
9
11
13
15
GMH [mbar]
hard walls
soft walls



F0 [Hz]
111
110
109
108
107
106
105
104
103
102
101
5
7
9
11
13
15
GMH [mbar]
hard walls
soft walls



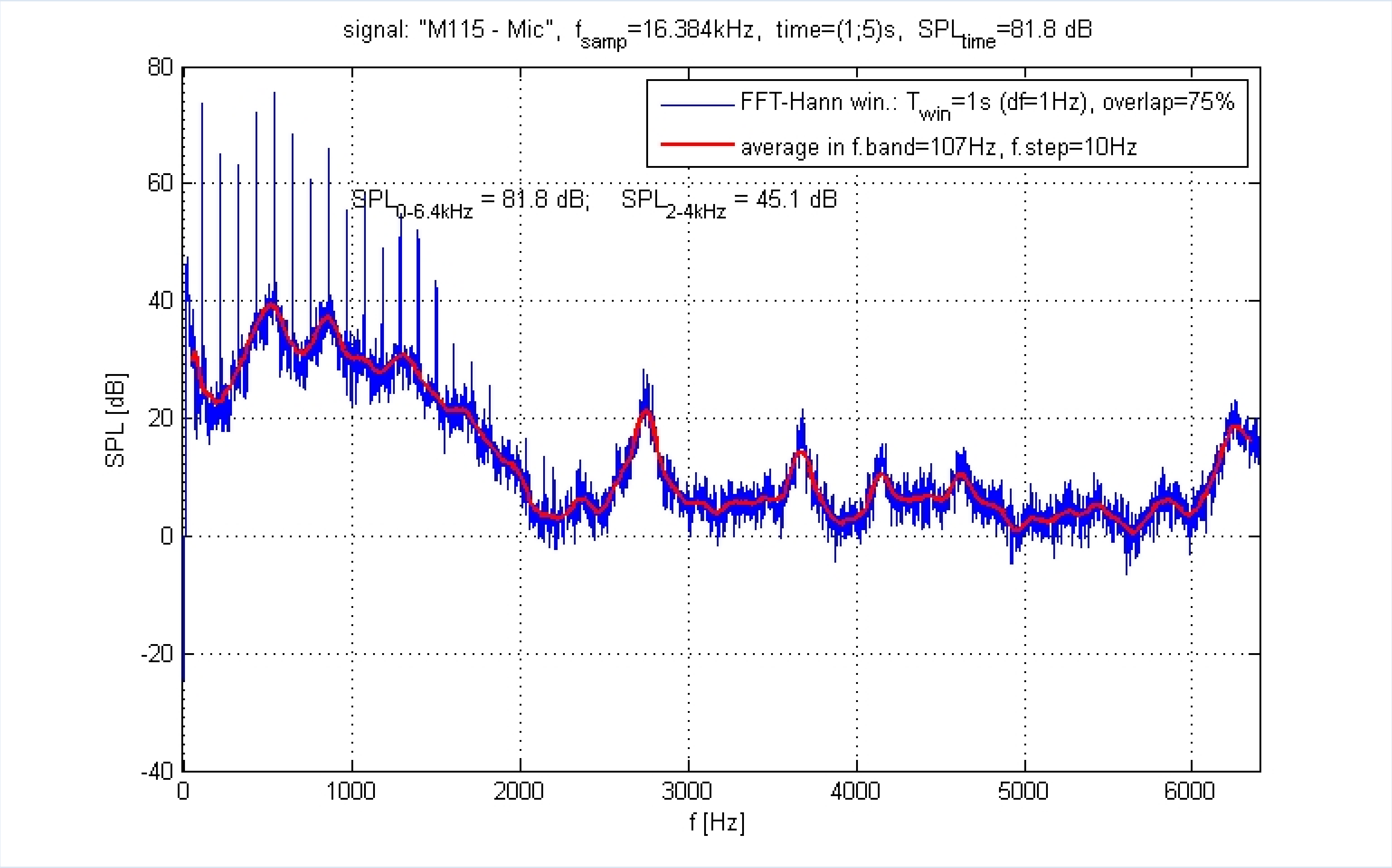
SPL 20cm [dB]
82
80
78
76
74
72
70
68
66
64
5
7
9
11
13
15
GMH [mbar]
hard walls
soft walls



GW [mm]
2,50
2,40
2,30
2,20
2,10
2,00
1,90
1,80
5
7
9
11
13
15
GMH [mbar]
hard walls
soft walls

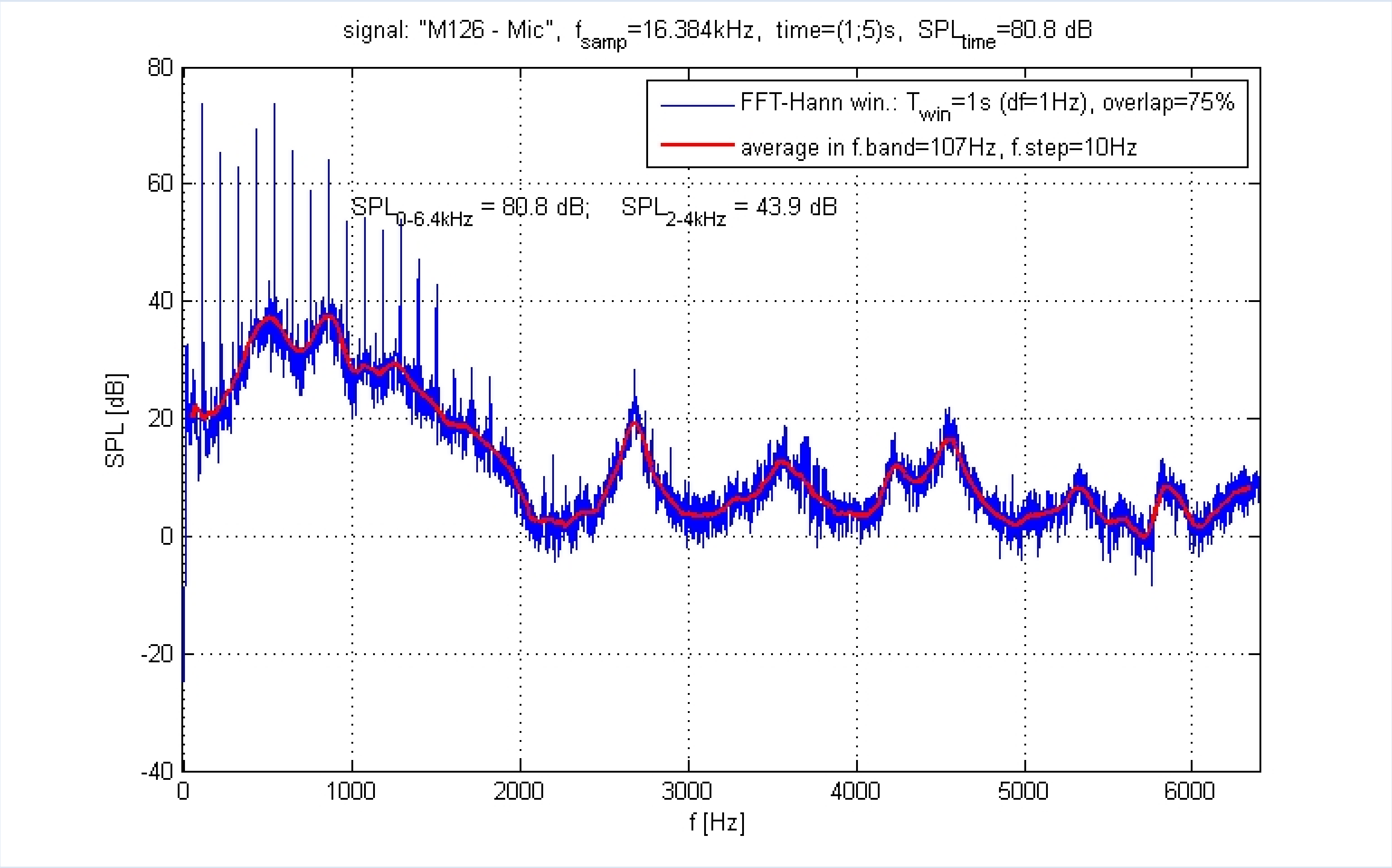
RESULTS

- **Sound pressure spectra, hard VT, p_{VF} = 10 mbar, f0 = 107 Hz**



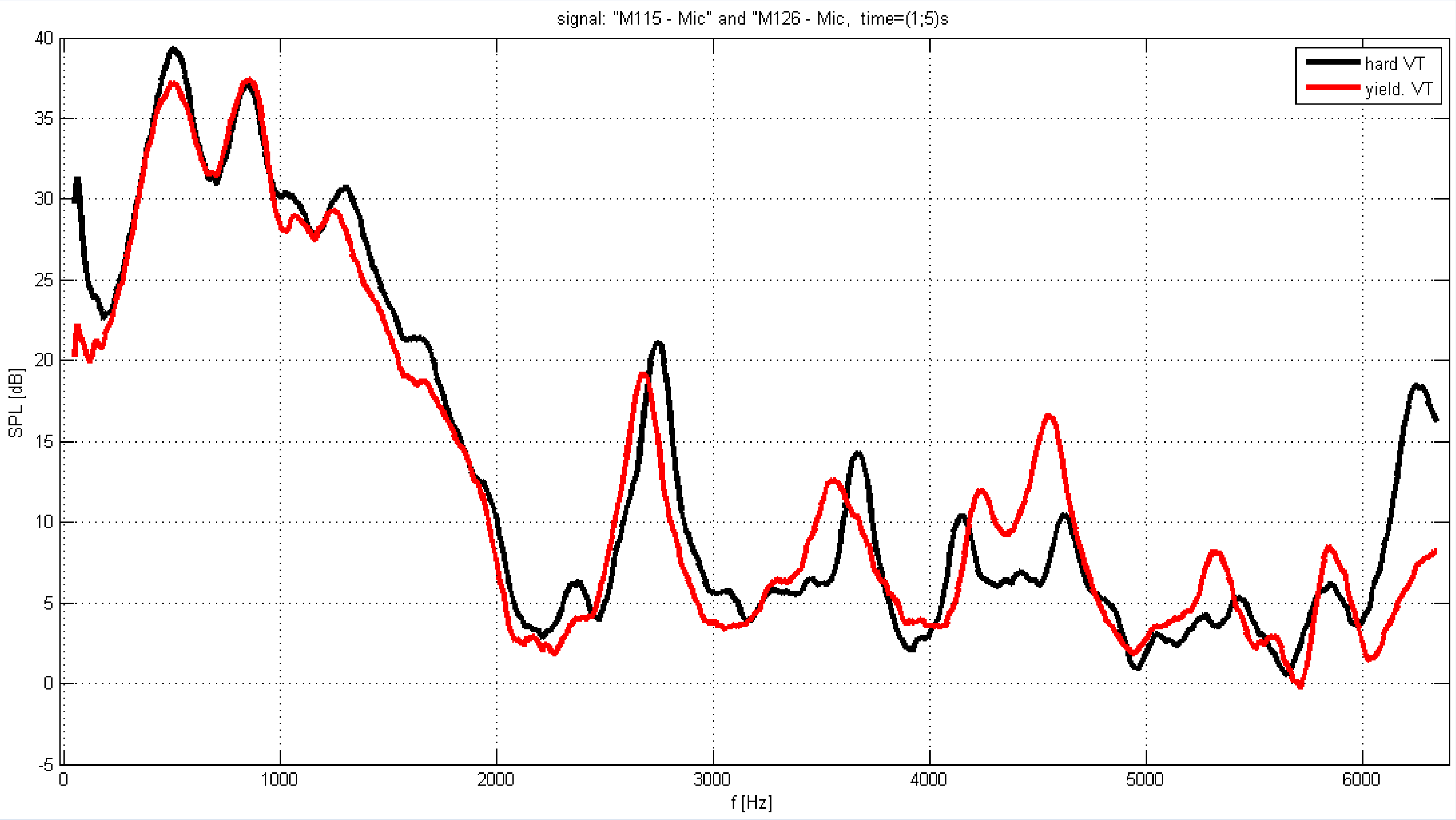
RESULTS

- **Sound pressure spectra, soft VT, p_{VF} = 10 mbar, f0 = 107 Hz**



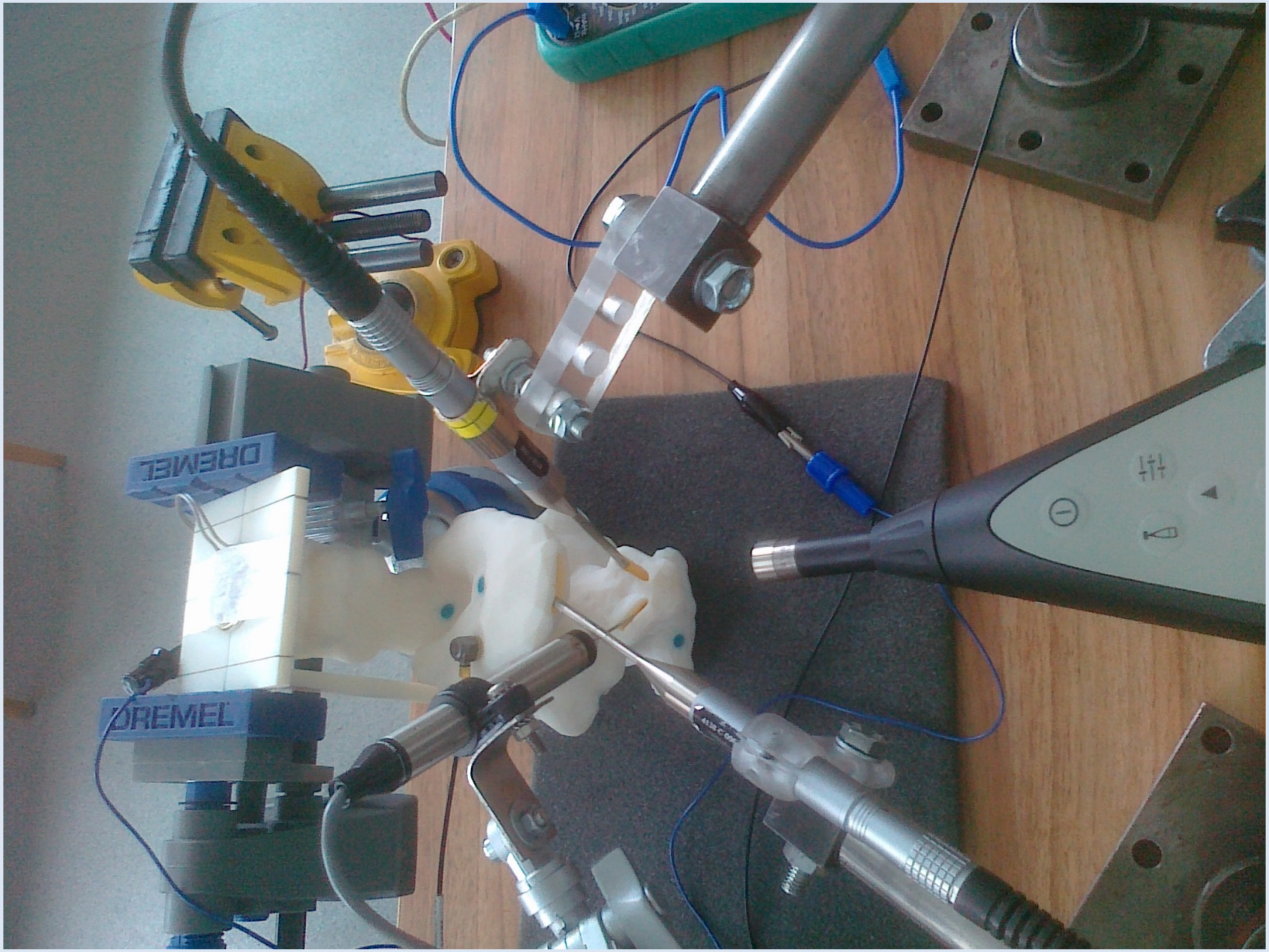
RESULTS

- **Sound pressure spectra, hard x soft VT, p_{VF} = 10 mbar, f0 = 107 Hz**



RESULTS

- **Excitation by 20mm speaker placed instead of VF**



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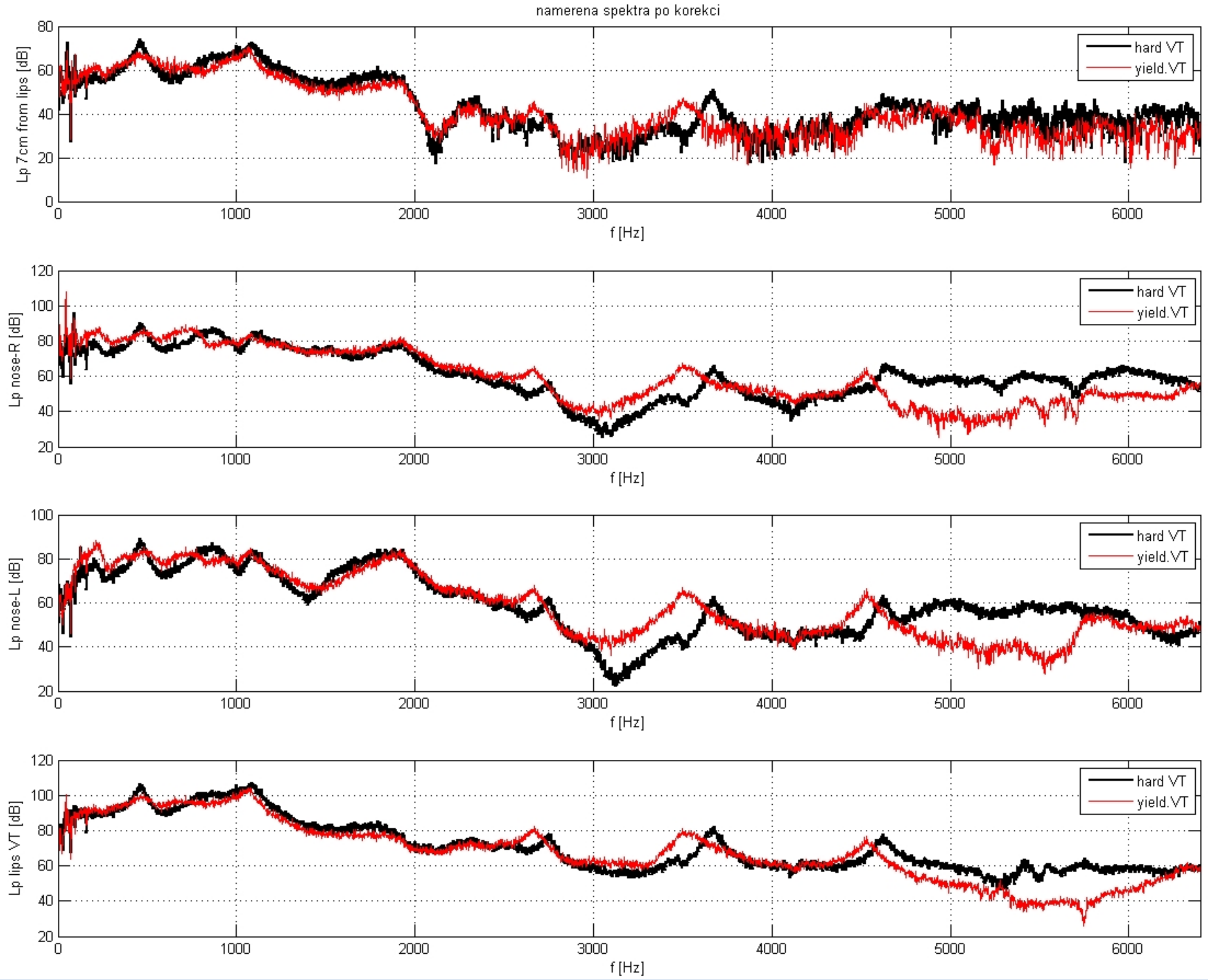
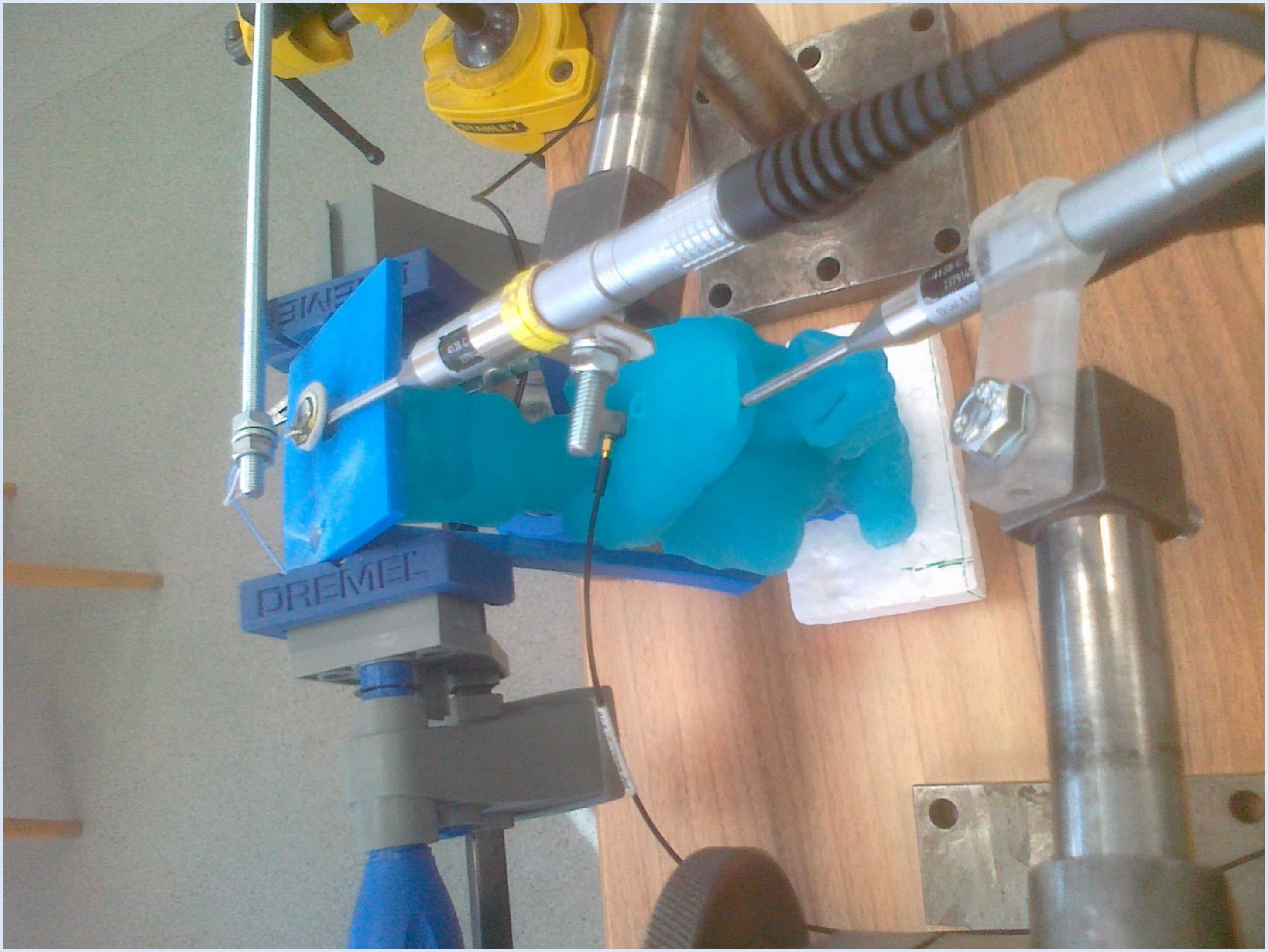


RESULTS

- **Excitation by 20mm speaker – transfer function**



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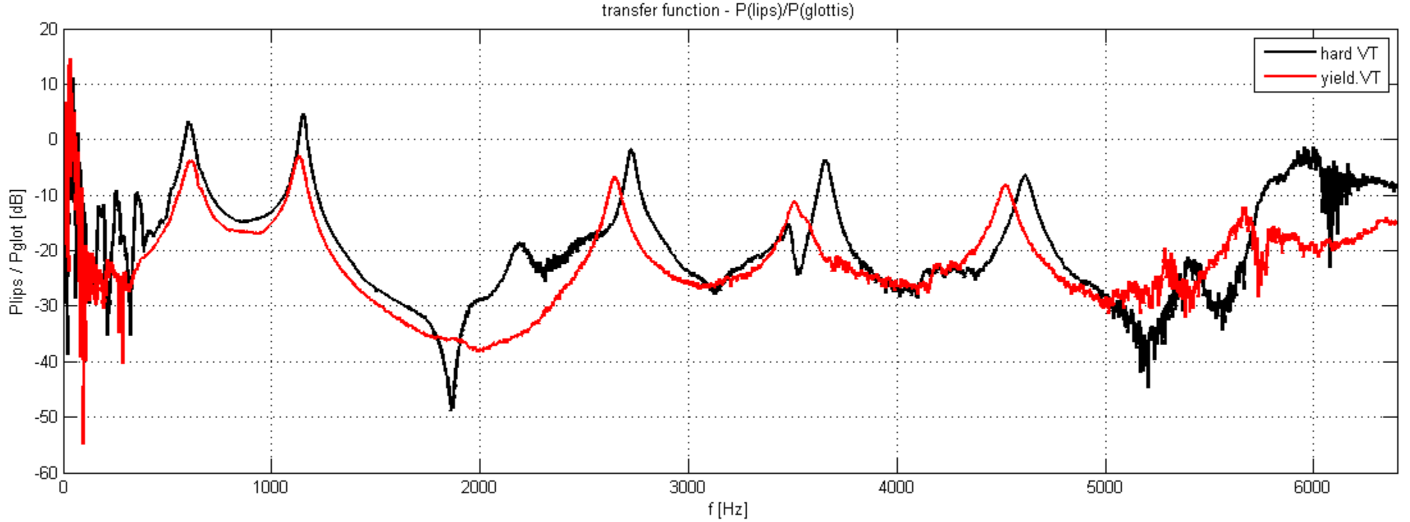

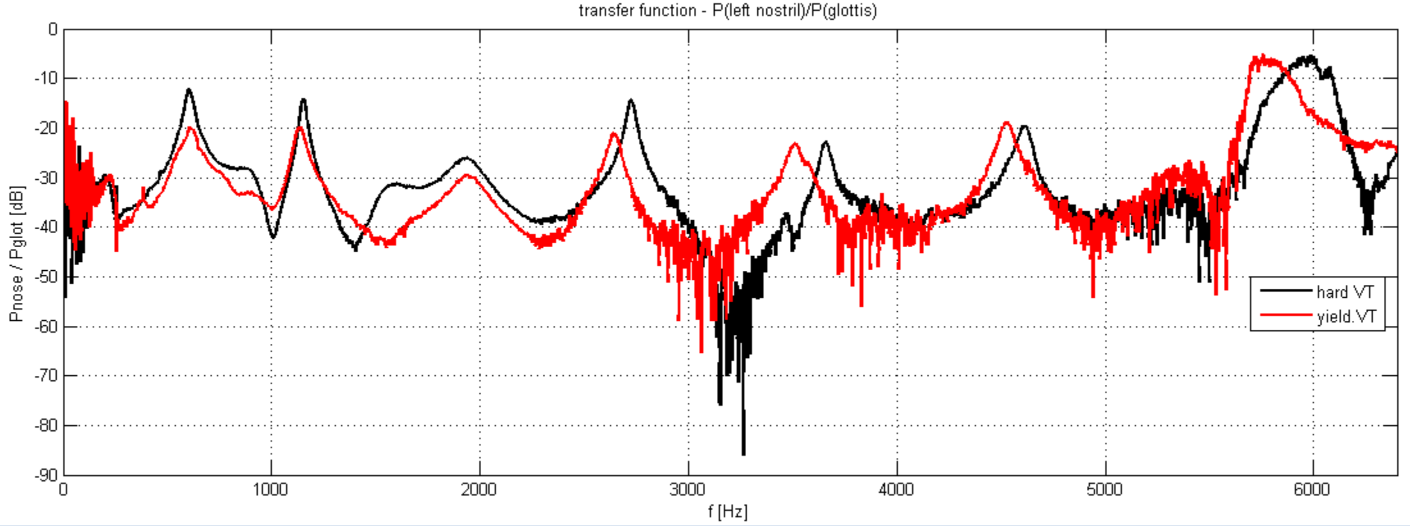

CONCLUSION

3D models of the human VT and NT, based on the CT registrations, have been improved by modelling the damping and visco-elastic properties of the boundary tissues of the models.

Experimental investigation of acoustic characteristics of the models was performed on vocal folds replicas. Such investigation is necessary for verification of the numerical simulations and for studying in detail the voice characteristics which are difficult to investigate in humans.

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