MEASURING SPEECH INTELLIGIBILITY REDUCTION DUE TO FACE MASKS

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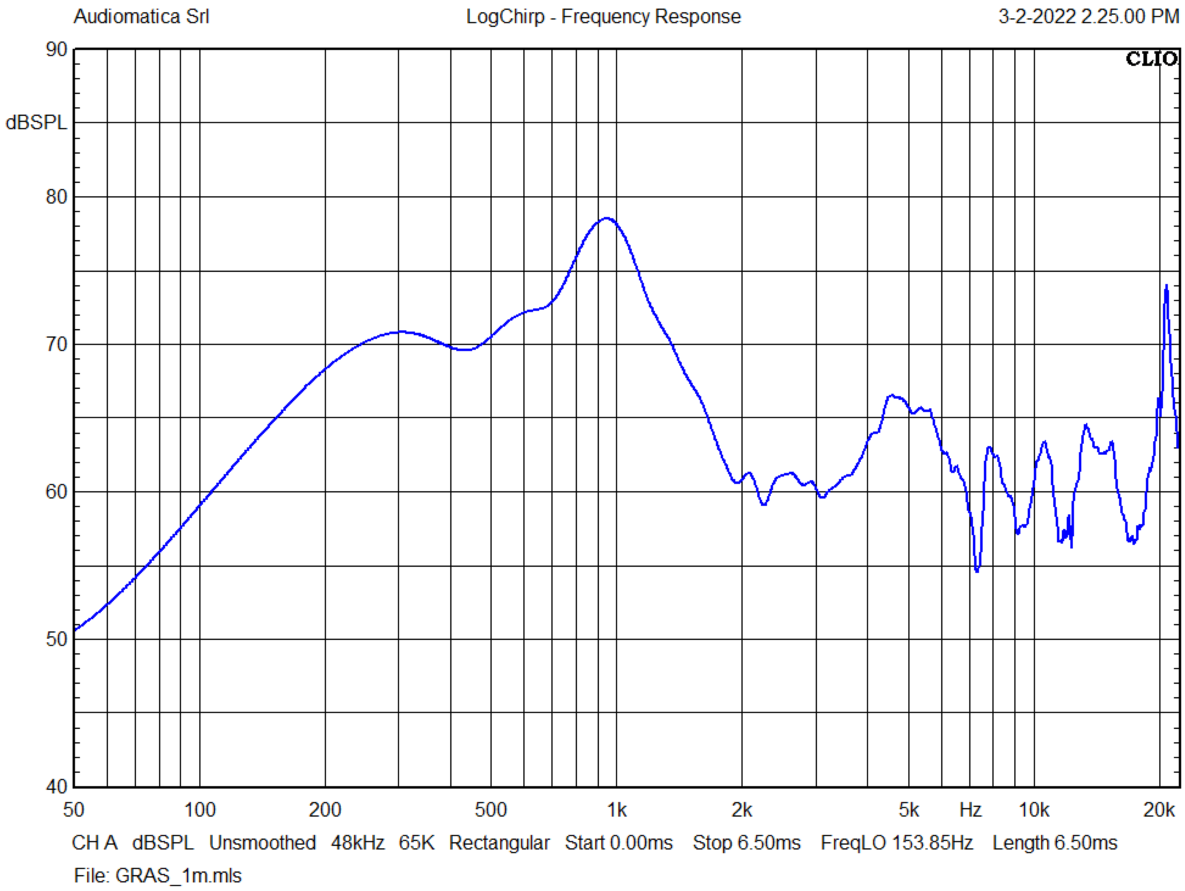
While the global Covid-19 pandemic is in remission at this stage (At least in Europe in March 2022), the use of face masks can be expected from now on to be very common in a large number of applications.

Using a face mask makes verbal communication more difficult, the lack of visual cues is one of the reasons but, above all, the mask has an important influence on speech propagation.

We were curious about quantifying the intelligibility loss when wearing a face mask. A brief bibliography research found many recent articles about the impact of Personal Protecting Equipment PPE on speech intelligibility, but the only article we were able to found which has Speech Transmission Index STI measured data dates back to 2016: Palmiero AJ, Symons D, Morgan JW 3rd, Shaffer RE. "Speech intelligibility assessment of protective facemasks and air-purifying respirators." J Occup Environ Hyg. 2016 Dec;13(12):960-968.

We decided to directly investigate the matter and gather some data setting up a simple experiment using a Gras model 44A mouth simulator and the indirect IEC 60268-16 Speech Transmission Index measurement technique as implemented in CLIO 12.5. Our test setup does not claim to be scientifically perfect, it is a first simple evaluation to understand the extent of the phenomenon. If the results are interesting enough we migth think to repeat the experiment in an anechoic chamber.

We put the Gras mouth simulator on a stand and measured its response at 1 m distance:



Using CLIO 12.5 STIPA Signal Equalizer function (see our application note 13 – Speech Intelligibilty Assessment Using CLIO) a pink noise shaped with an IEC 60268-16:2011 male spectra (signal available under CLIO Signal folder) can be pre-distorted to virtually apply equalization to our mouth simulator.

We then feed the pre-distorted signal to the mouth simulator and set the CLIO output level to read 60 dB(A) sound pressure level at 1 m distance. In this way our mouth simulator is linear and calibrated to a normal speech level.

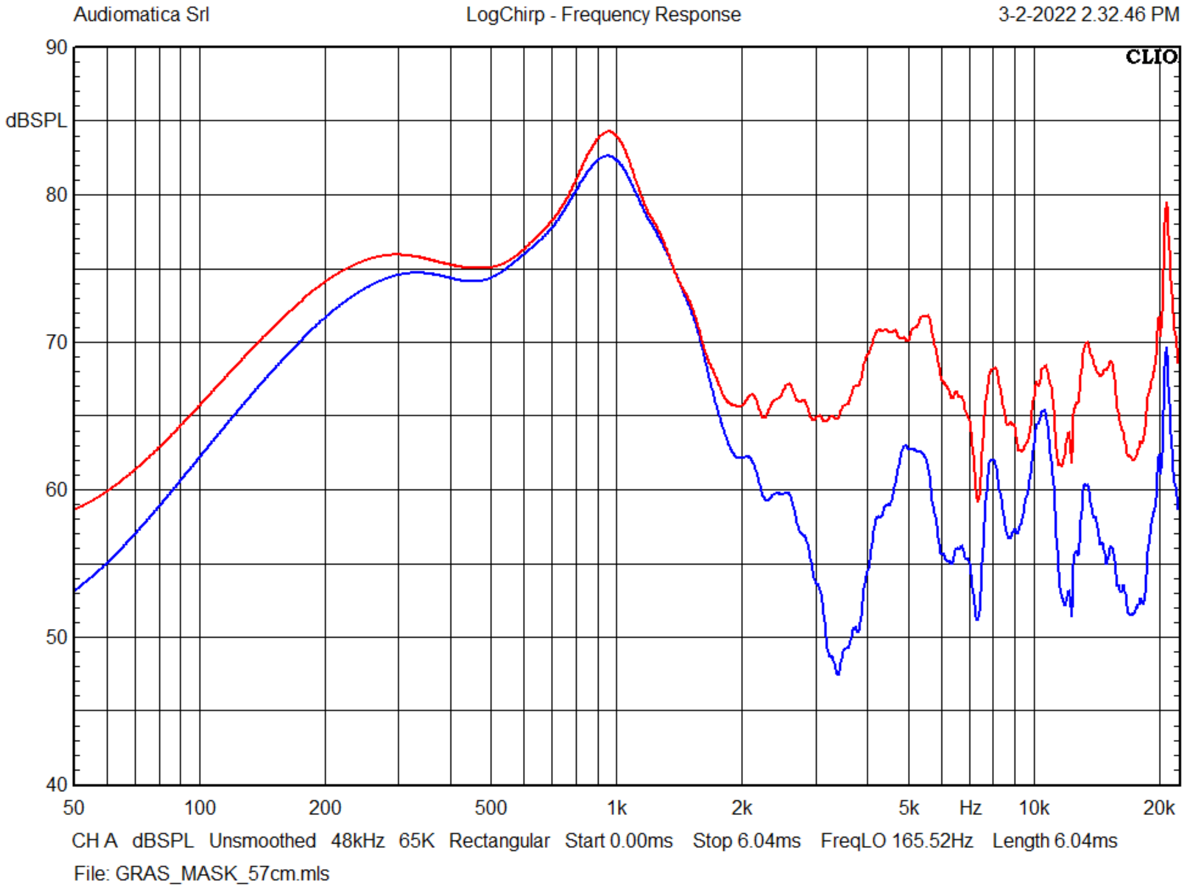
We then moved the measurement microphone to 60 cm from the mouth to simulate a hypothetical situation where two people are speaking at a relatively short distance. We measured the impulse response of the mouth at this distance and the relative SPL spectrum in octaves, the latter is related to the previously normalized level of 60 dB(A) at 1 m. The impulse response includes the effects of room reflections, in this case the room is a typical office space with a reverberation time of about 0.5 s.

Figure 1: Mouth without mask

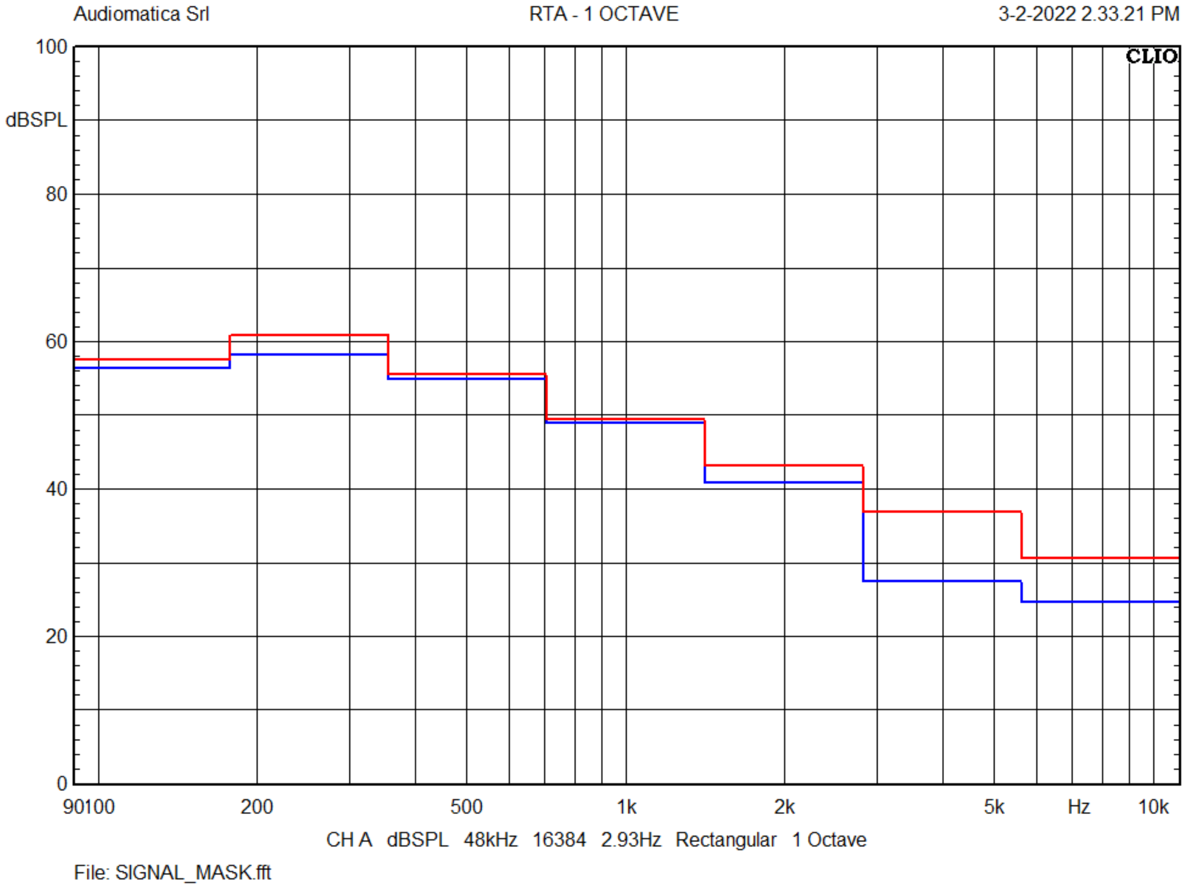
Figure 2: Mouth with FFP2 mask

We repeated the same measurements with the mask mounted onto the mouth simulator.

The resulting frequency responses (with room reflections removed by time windowing) are shown in the next figure, red curve is without mask, blue curve with mask:

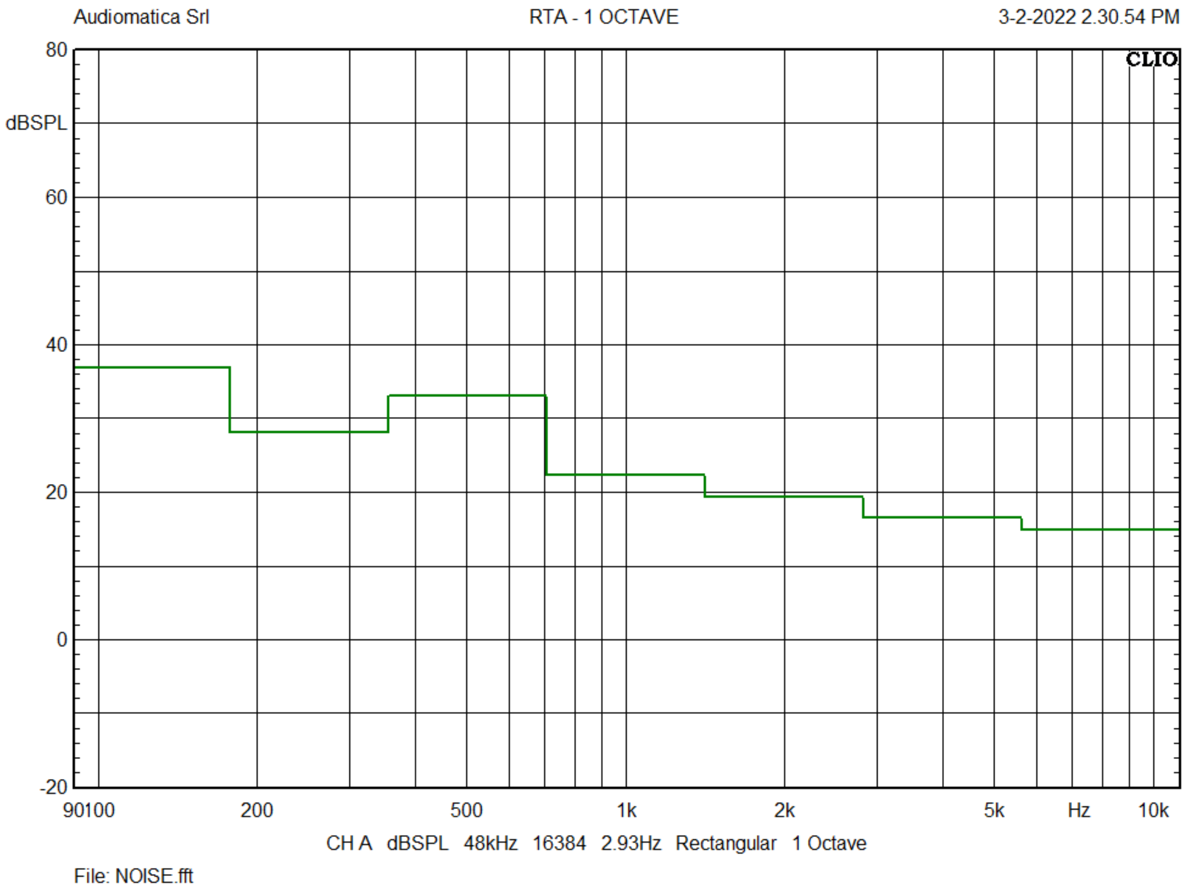


The octave band spectra measured are:



The level reduction and the effects of the reflections due to the presence of the mask are clearly visibile, but how does this affects the Speech Intelligibility? We can use the STI to investigate that. We almost have all the elements needed to calculate STI using the indirect method, we have the Impulse Response, the Signal spectra and we are missing only the Noise spectra.

We should measure the background noise of our office:



But we can also infer a typical background noise and check how the STI react to different background noise levels.

Using the background noise of the office, which is quite low at about 32.5 dB(A), the results are:

Background noise (dB(A))	STI w/o Mask	STI with Mask
32.5	0.84	0.77

Thus, in conditions which are very good for the speech transmission: low reverberation, low background noise, SNR in excess, the STI reduction is sensibile at about -0.07. Of course we are lowering the STI from a very high value to a relatively still high value, then the perception of loss of intelligibility will be rather mild.

It is interesting to see what might happen if the SNR deteriorates, we can simulate various levels of background noise using NR spectra:

Background noise (dB(A))	STI w/o Mask	STI with Mask
(NR 30) 38.2	0.79	0.70
(NR 40) 47.7	0.62	0.51
(NR 50) 57.6	0.34	0.27

The STI reduction is always not negligible.

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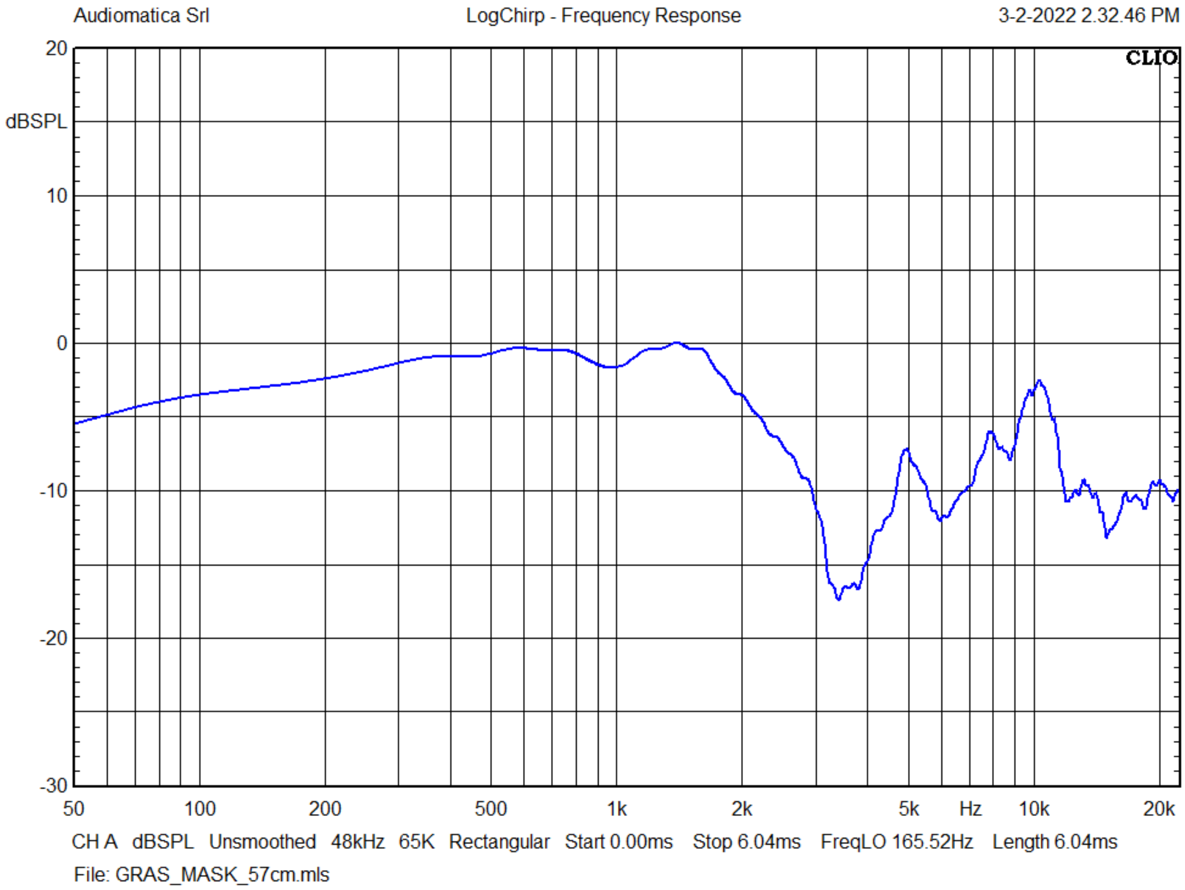
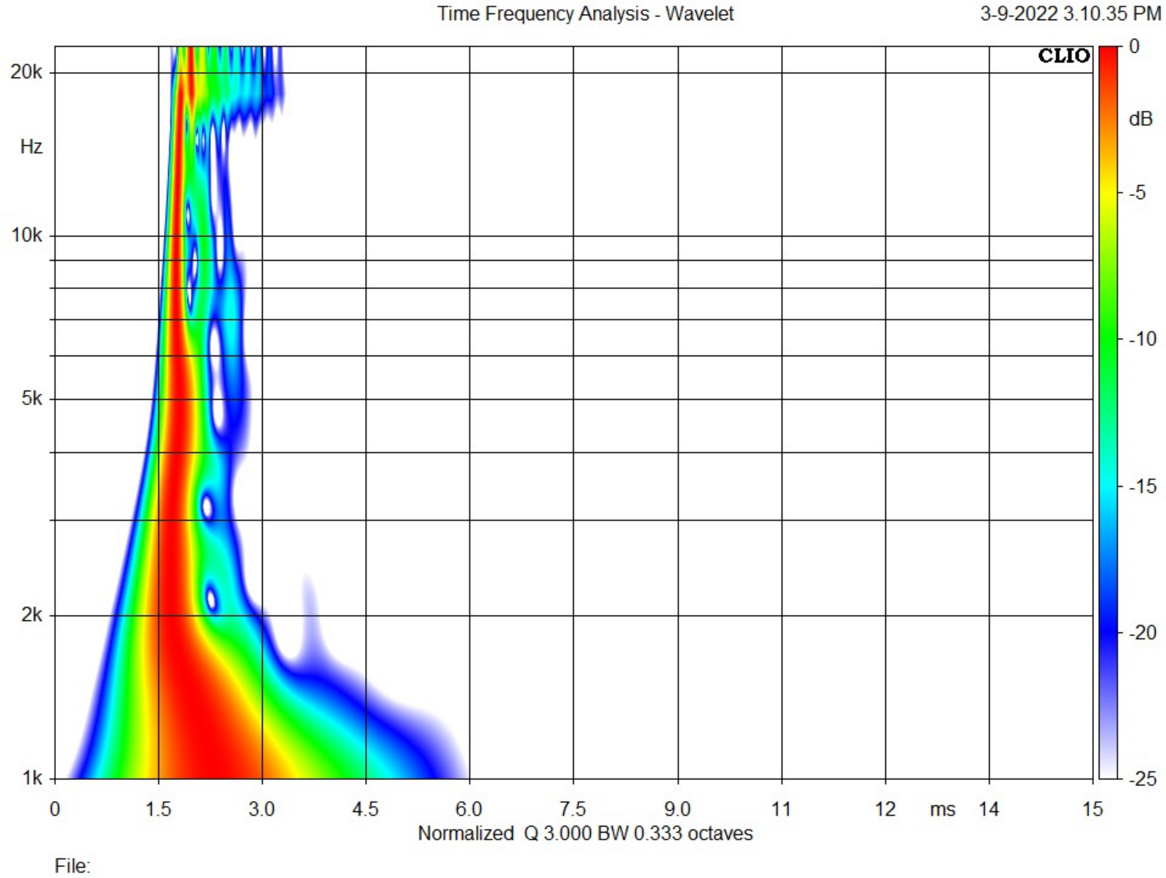
We were able to measure the STI reduction associated to a face mask, in this case we tested a single FFP2 type mask which is currently the most used model in our country. The STI reduction, even in a case which is not critical, i.e. in an office with low reverberation, ranges from 0.07 up to 0.11 depending on the background noise level and spectra.

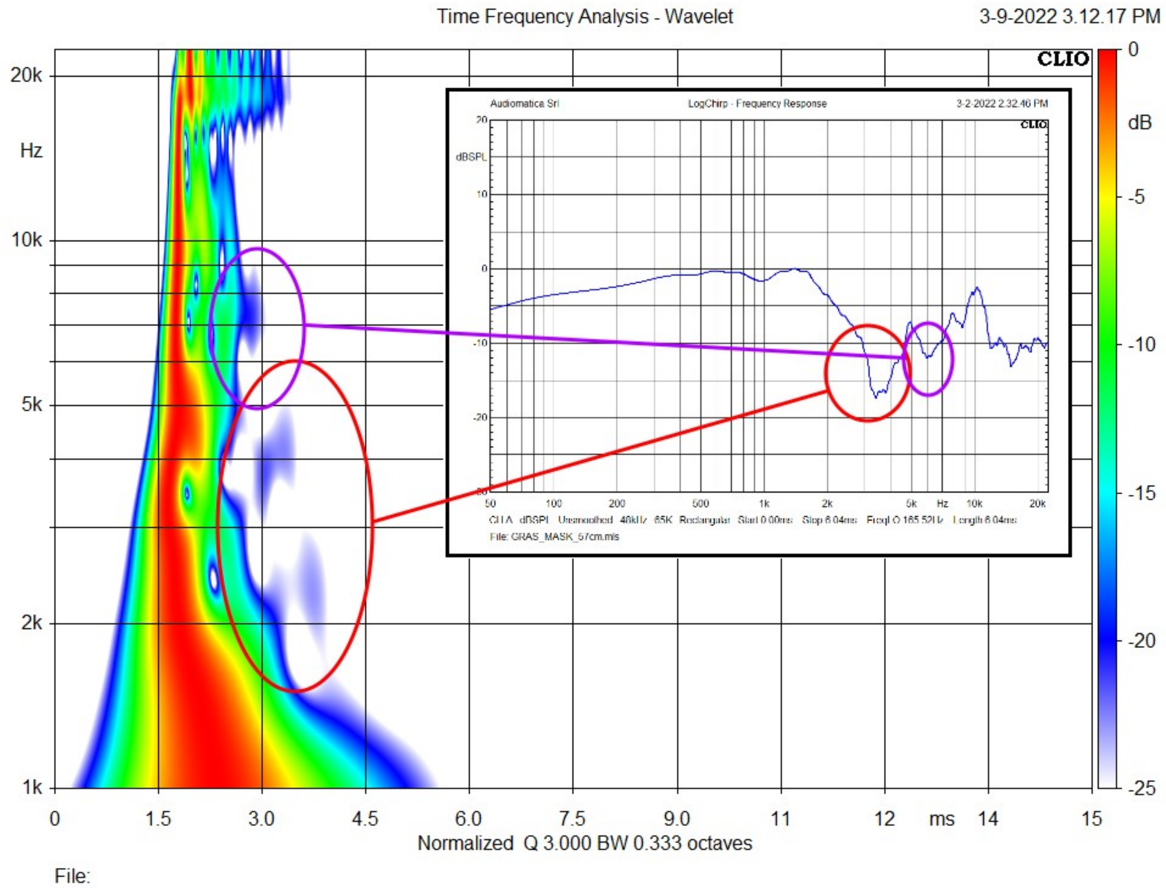
We infer that part of the STI reduction is due to the sound attenuation introduced by the mask, which by definition should block air stream from mouth, this effect is clearly seen by comparing the responses of the artificial mouth without and with mask. The following graph shows the attenuation between the two cases:



It can be seen that in the 3-4 kHz region the attenuation reaches 15 dB.

The mask introduces also time dependent effects, i.e. unwanted reflections in the area enclosed by the mask in front of the mouth, these effects are clearly visible using Time-Frequency Wavelet Analysis. See following figures, first figure is without mask and second with mask. It can be seen that there are reflections/resonances which are causing the frequency responses difference.


Time Frequency Analysis - Wavelet
3-9-2022 3.10.35 PM
CLIO
20k
Hz
10k
5k
2k
1k
0
1.5
3.0
4.5
6.0
7.5
9.0
11
12
ms
14
15
Normalized Q 3.000 BW 0.333 octaves
File:
dB
0
-5
-10
-15
-20
-25


Time Frequency Analysis - Wavelet
3-9-2022 3.12.17 PM
CLIO
20k
Hz
10k
5k
2k
1k
0
1.5
3.0
4.5
6.0
7.5
9.0
11
12
ms
14
15
Normalized Q 3.000 BW 0.333 octaves
File:
dB
0
-5
-10
-15
-20
-25
Audiomatica Srl
LogChirp - Frequency Response
3-2-2022 2.32.46 PM
dBSPL
File: GRAS_MASK_57cm.mls

This short report does not have the ambition to be a complete treatment of the subject. We tested a single sample of a single mask FFP2 type. A rigorous research should involve testing over a larger set of samples.

The choice of using the artificial mouth and measuring the effects in our office environment can also be challenged. Other studies point out that at least an artificial head should be used to correctly model the effects of the face masks on speech. Using an anechoic chamber also allows to separate the effects of the room in the STI reduction.

This is just a first approach that demonstrates that through the measurement of the STI it is easy to characterize the loss of intelligibility due to the use of face masks.

Using CLIO 12.5 it is straightforward to carry out STI tests with both indirect and direct measurement methods. Our setup required only twenty minutes from concept to measurement and gave us reliable and repeatable results.

We would like to thank Ph.D. Andrea Farnetani of Materiacustica for helping us with the above measurements.