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Technical document

Wearing of personal protective masks. Assessment of risk of reduced intelligibility of crew exchanges in the cockpit and impact on CVR recordings.

RÉPUBLIQUE FRANÇAISE
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1. PURPOSE

To assess the impact of wearing personal protective masks on the quality of spoken exchanges and their intelligibility on CVR recordings.

The method consisted of making a comparative measurement between a situation where masks were not worn and a situation where different protective mask models were worn.

The work was carried out in the BEA's audio-CVR analysis laboratory.

2. ASSESSMENT METHODS

There were two tests.

The first "subjective" test consisted of reading a text close to a cockpit area microphone (CAM) wearing a crew headset (Sennheiser HMEC-25) and various mask models (different materials and protection levels).

The second "pseudo-objective" test consisted of emitting a reference stimuli (white noise) with a loudspeaker and placing, in succession, various mask models between the sound source and the boomset microphone of the crew headset.

3. MASK MODELS ASSESSED

- A single-use "surgical" mask (nonwoven filter)
- An FFP3 protective mask (equipped with an exhalation valve)
- Cloth mask No 1 (made of woven cotton fibre)
- Cloth mask No 2 (made of Polyethylene terephthalate (PET) "fleece" fibre)

View of mask models

4. PERFORMANCE OF SUBJECTIVE TEST

Appendix 1 presents the test installation made up of:

- A pair of loudspeakers broadcasting the background noise of a cockpit (sample taken from an A320 cockpit).

- A PC dedicated to the audio activities and the Samplitude multi-track audio editing application.

- An A320 CAM placed on a height-adjustable mount.

- An A320 CAM pre-amplification unit.

- A crew headset (Sennheiser HMEC-25 CAP).

- A power supply and interface unit for the headset boomset microphone and the associated audio connection.

- A portable digital recorder (stereo TASCAM DR-40).

An operator wearing a protective mask and a crew headset read the same text against background noise similar to that in a cockpit. The operation was repeated for each of the protective mask models to be assessed. The microphone signal sent by the microphone interface unit was recorded at the same time as the signal picked up by the CAM.

5. PERFORMANCE OF PSEUDO-OBJECTIVE TEST

Appendices 2, 4b and 4c present the test installation made up of:

- A loudspeaker on which the protective mask and crew headset were placed and which transmitted a reference signal.

- A PC connected to the powered speaker which generated the reference signal.

- A crew headset (Sennheiser HMEC-25 CAP).

- A power supply and interface unit for the headset boomset microphone and the associated audio connection.

- A portable digital recorder (stereo TASCAM DR-40).

A reference signal was continuously played in the loudspeaker. The masks were placed in succession on the dedicated mount and the signal picked up by the boomset microphone of the crew headset was recorded on the portable recorder.

6. COMPARATIVE MEASUREMENT METHOD

The signal was acquired for a period of 1 to 2 minutes during each test.

The audio files were then listened to (principally as part of the subjective assessment) to assess the modifications/masking introduced by the protective equipment (different mask models).

A reference signal over a 25 s period was selected (section of speech in the subjective assessment case and section of white noise for the pseudo-objective assessment). In both cases, the frequency spectrum of the sample was compared with the reference sample (recorded without the wearing of a mask).

The 25 s analysis sample was represented in the form of a Power Spectral Density (PSD) and a third octave noise spectrum.

Appendices 3a, 3b and 4a give the comparative measurements made.

7. RESULT

The analysis of the data collected during the two test phases brings to light the following points:

Subjective assessment

A CVR analyst listened to the recordings made during the subjective test and made the following observations:

- Wearing the surgical mask does not significantly attenuate the loudness of speech; no reduction in the intelligibility of the speech was detected.

- Wearing the FFP3 mask does not, in principle, significantly attenuate the loudness of speech; there is, however, a notable reduction in the high-frequency components of the voice band; the words sound as if they are deadened or muffled which might significantly reduce the intelligibility of the speech.

- Wearing cloth mask No 2 does not significantly attenuate the loudness of speech; a slight reduction in the high-frequency components of the voice band can be detected; speech is very slightly muffled but this does not seem to reduce its intelligibility.

Note 1 ___ Observation of spectra produced during the subjective assessment (appendix 3):
The method used for producing the frequency spectra (integration of spectra over 25 s) proved ill-suited for a comparative assessment of voice activity which is naturally composed of a succession of sound events with a variable spectral content. The integration of a number of spectra tends to favour the display of the general noise (predominance of background noise) which is confirmed by the spectrum illustrations given in appendix 3; practically no difference can be visually detected between the audio pick-ups made during the test of the three mask models. The same observation was made with respect to the three CAM pick-ups.
It would therefore be preferable in the scope of similar tests, to isolate a single reference phenomenon in the speech, to integrate the small number of spectra in which it is present and to compare the curves produced.

Note 2 ___ Robustness of assessment method:
The subjective assessment is subject to the variability in the operator's quality and loudness of speech during the successive tests. The method proved not to be very robust.

Pseudo-objective assessment

The comparative analysis (appendix 4) of the noise spectra based on audio pick-ups of reference stimuli gave rise to the resulting observations:

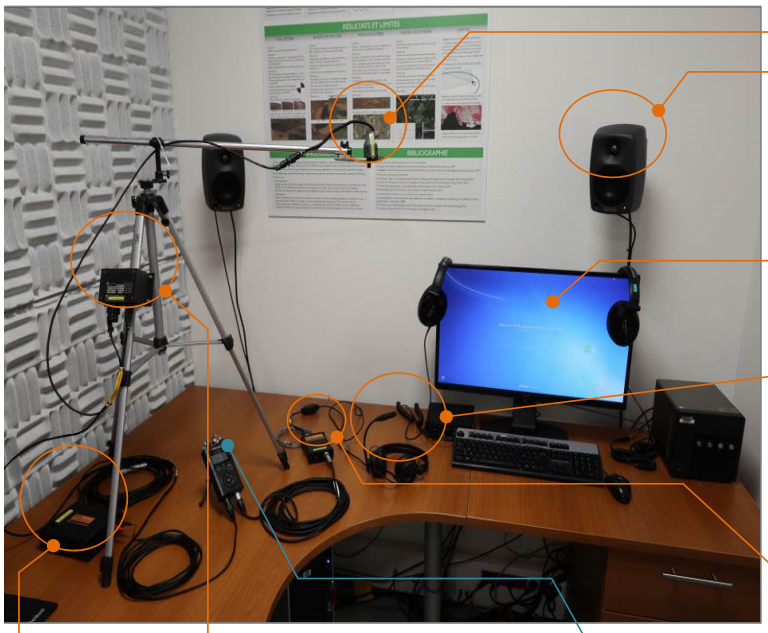
- Wearing a surgical mask does not result in a significant attenuation in the useful frequency band allocated to the voice activity (0 – 4kHz).

- Wearing a FFP3 mask may result in a substantial attenuation in the voice frequency band and beyond according to the position of the boomset microphone.

- Wearing cloth masks may result in a significant attenuation of the voice activity according to the model (density of material or weave).

Note ___ Robustness of assessment method:
The pesudo-objective assessment was carried out based on an unchanging reference which covered all of the passband of the pick-up system. The method is robust.

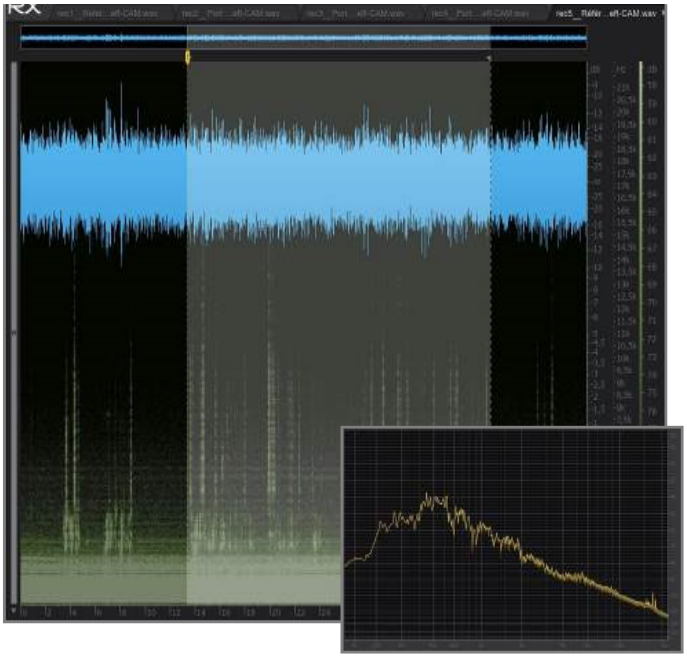
Appendix 1. Pick-up system for subjective assessment



The operator wore in succession each of the three mask models being assessed and read the same text.

The audio signals picked up by the boomset microphone and by the CAM were recorded; the frequency spectra were observed and compared with the reference datum.

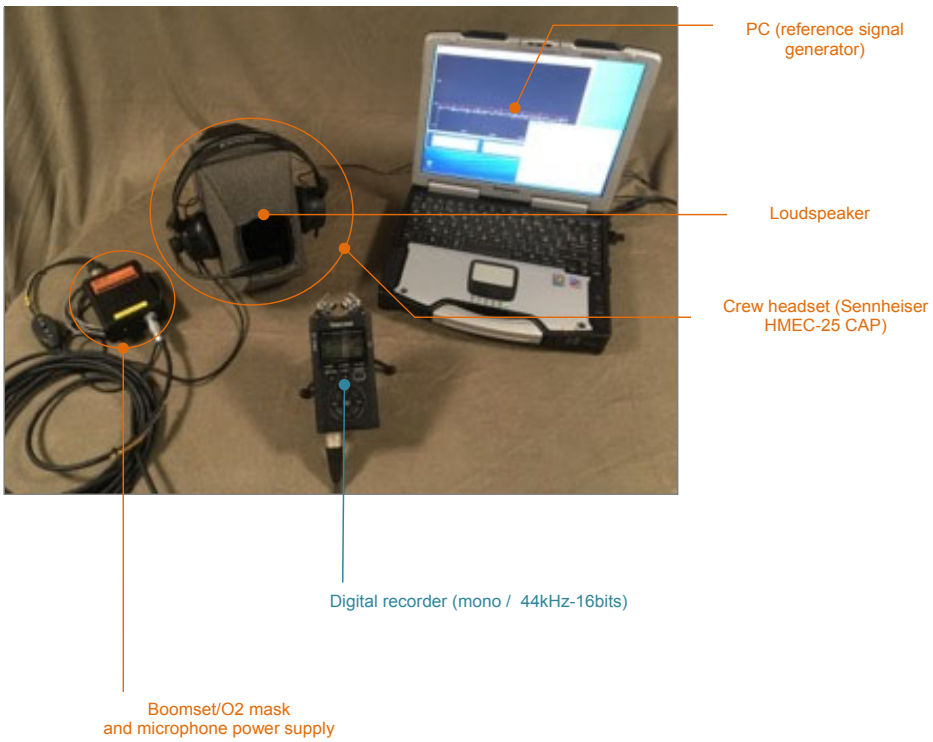
View of mask models



Spectra and waveform

Note: appendix 3 illustrates the spectra observed in the scope of this assessment.

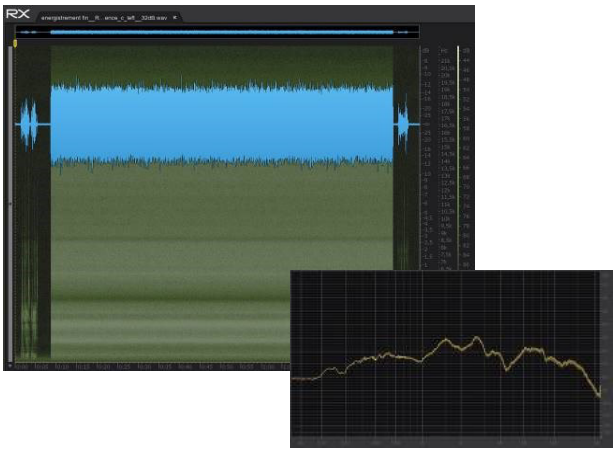
Appendix 2. Pick-up system for pseudo-objective assessment



View of mask models

The masks were placed in succession on the loudspeaker which continuously emitted the reference stimuli (white noise).

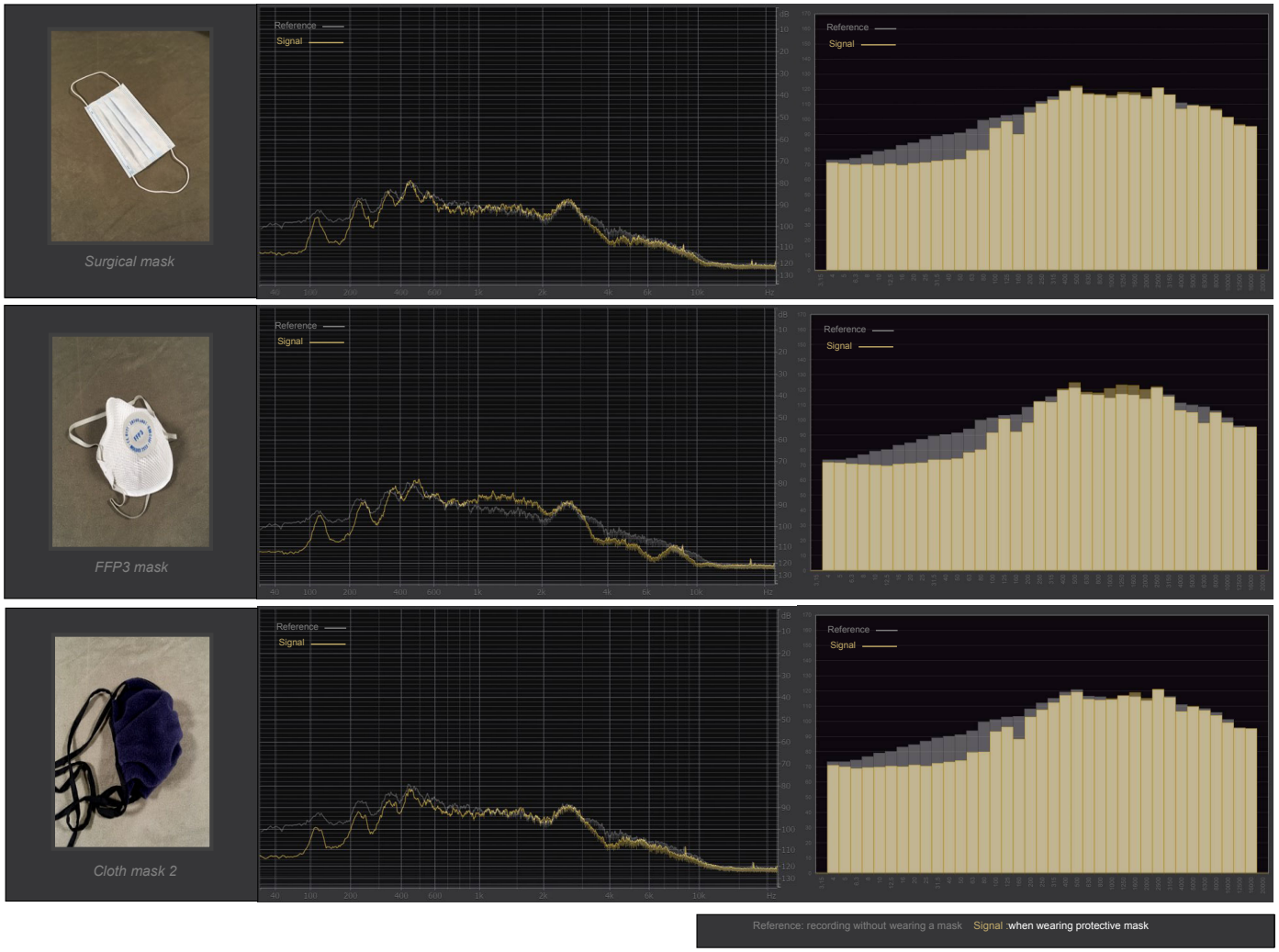
The audio signal picked up by the boomset microphone was recorded; the frequency spectra was observed and compared with the reference datum.



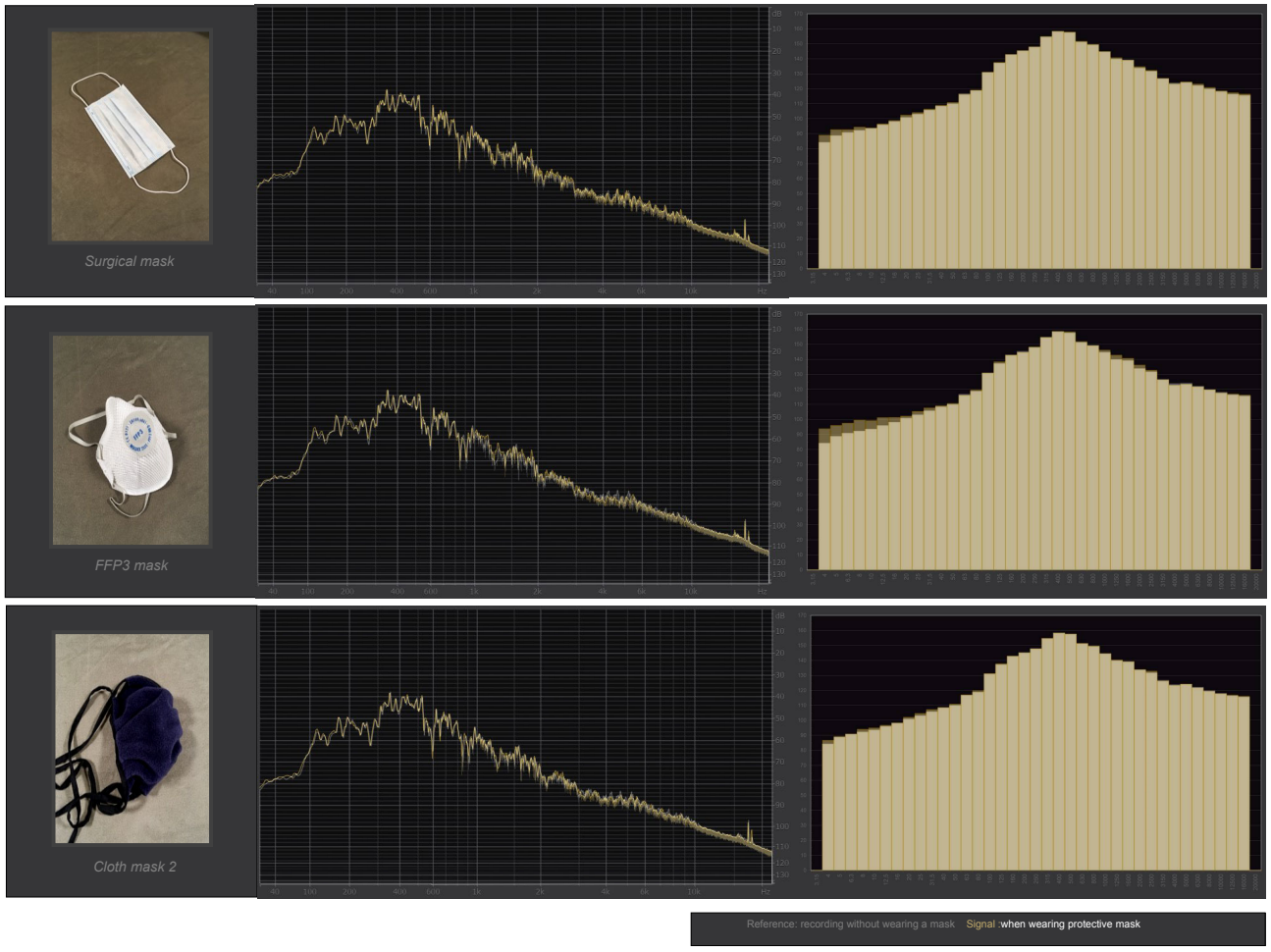
Spectra and waveform

Note: appendix 4 illustrates the spectra observed in the scope of this assessment.

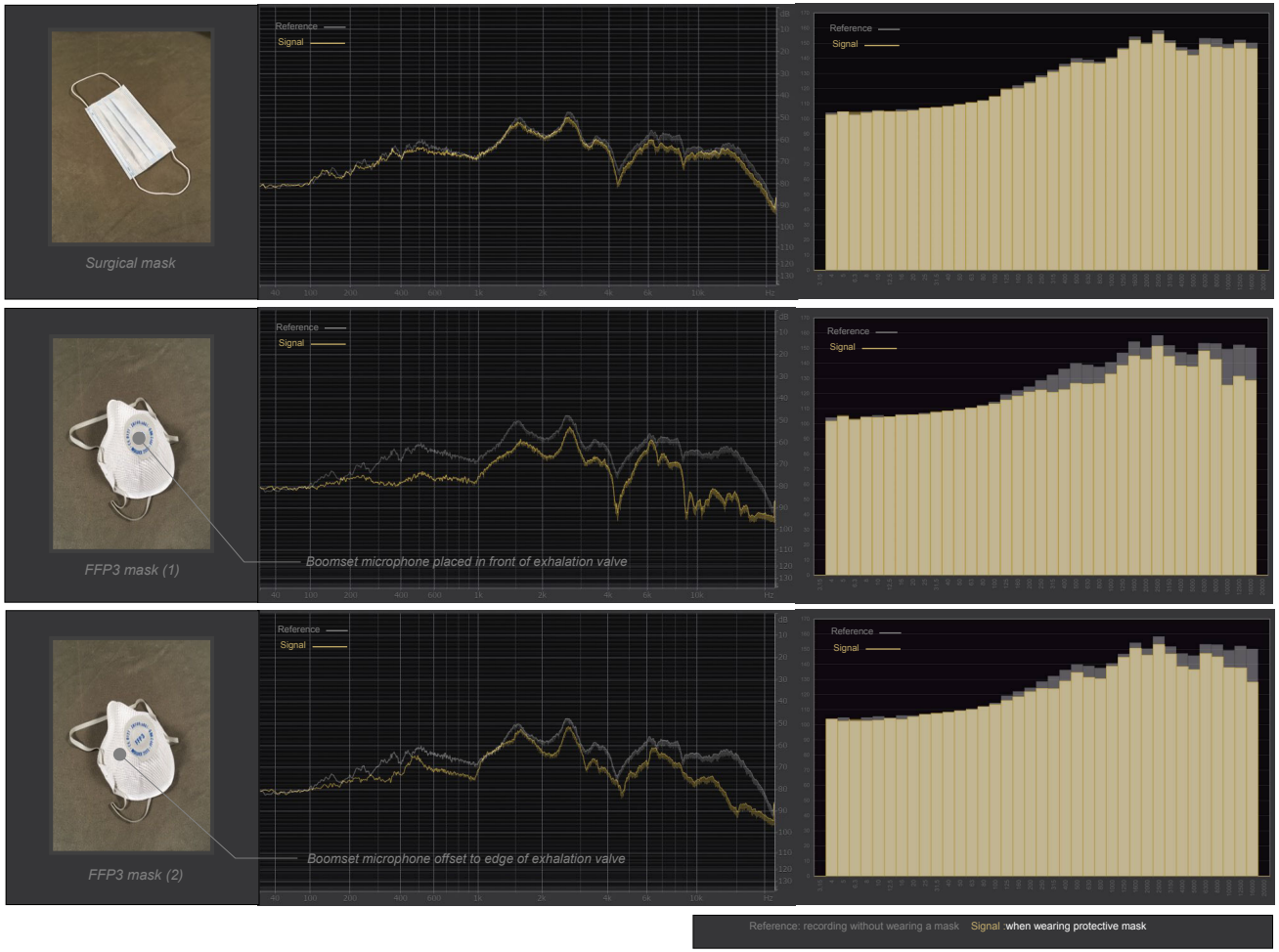
Appendix 3a_Comparison of subjective assessment spectra – Crew boomset microphone pick-up (PSD and third octave view)



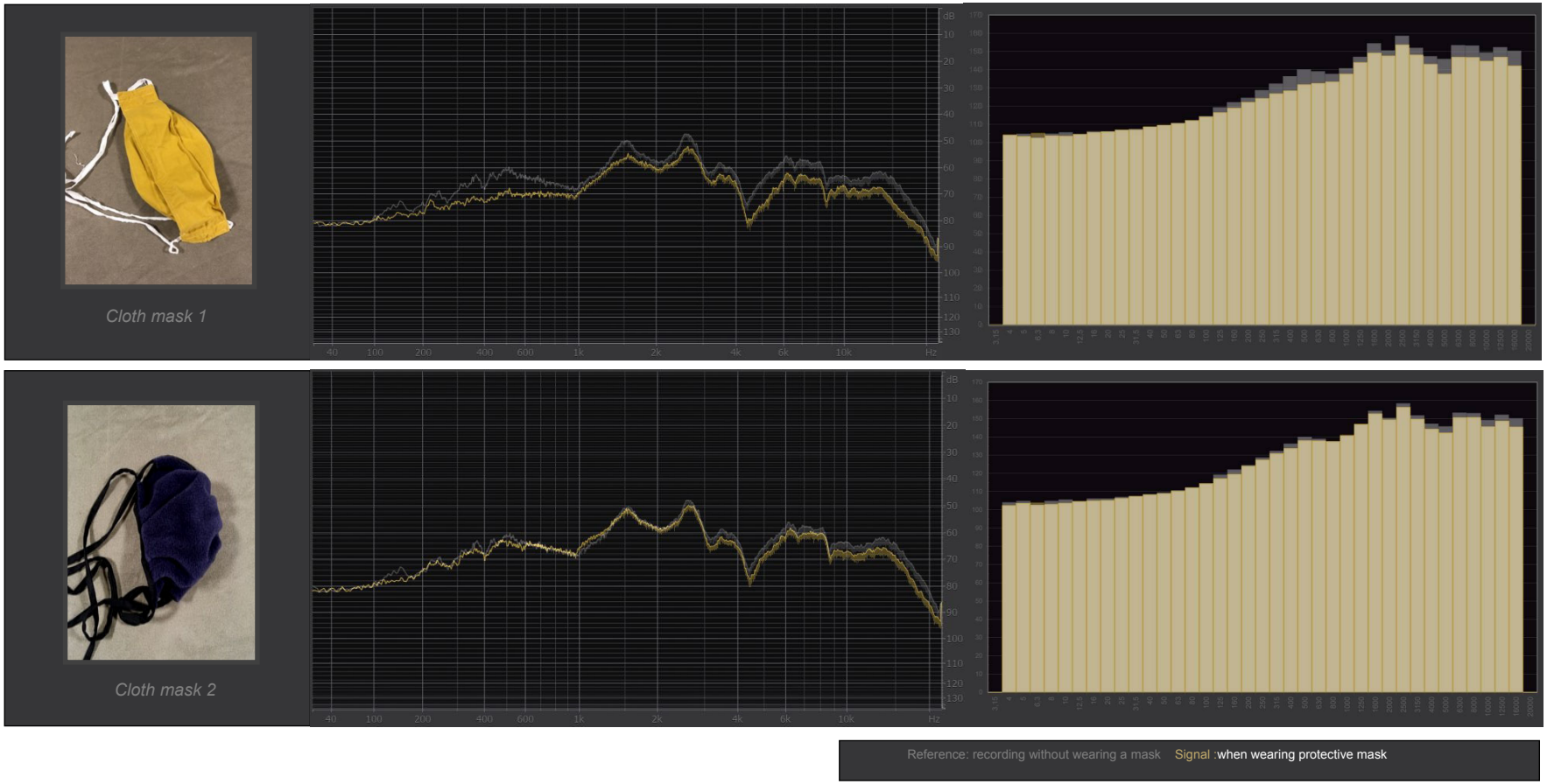
Appendix 3b_Comparison of subjective assessment spectra – CAM pick-up (PSD and third octave view)



Appendix 4a_Comparison of pseudo-objective assessment spectra – Crew boomset microphone pick-up (PSD and third octave view)



Appendix 4a (cont'd) Comparison of pseudo-objective assessment spectra – Crew boomset microphone pick-up (PSD and third octave view)



Appendix 4b __ View of protective equipment placed on stimuli emitter

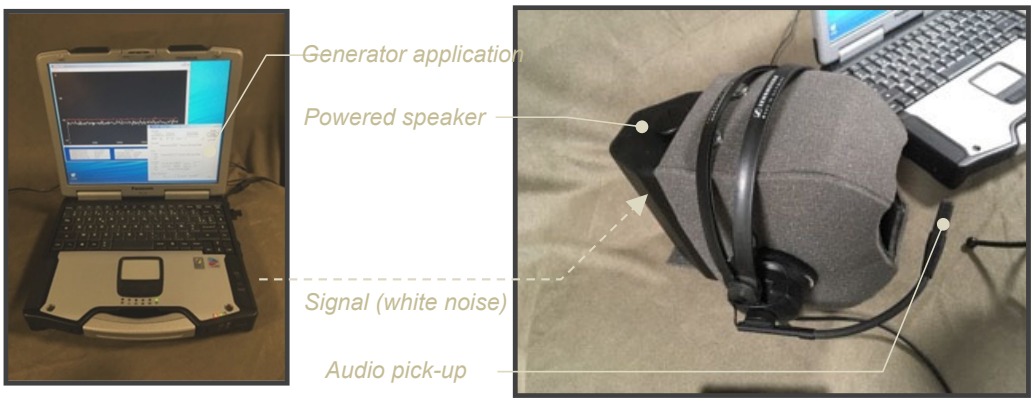
Surgical mask

FFP3 mask

Cloth mask 1

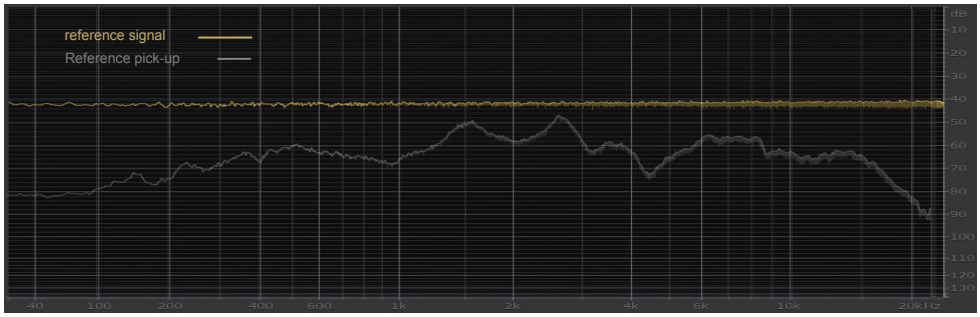
Cloth mask 2

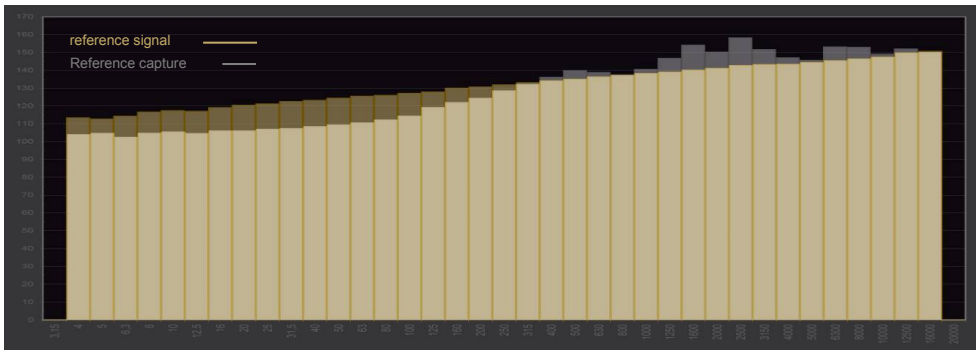
Appendix 4c _ Pseudo-objective evaluation - Description of stimuli emitter system



A software application generated a noise which could be adjusted in terms of type and level (pink, white, brown, etc. noise). The audio signal was sent to a powered speaker equipped with a headset mount. The crew headset was thus always placed in the same position and the test conditions could be reproduced. The noise generated for this test was a white noise (noise increased by 3dB per octave in the 0-20kHz band) to ensure a constant slope in the band of concern. Nevertheless, the geometry and small size of the headset mount caused a high distortion of the reference signal. This distortion was the result of the waves which originated at the heart of the mount rebounding several times, and of not respecting the acoustic distance of the speaker. The spectrum views below detail the overall transfer function of the system[(1)].

[(1)] Performance of PC sound board + performance of amplifier + performance of speaker (coupling of a tweeter and an 8 cm woofer) + acoustic performance of mount.





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