

EUHA Guideline

“Elk test” for percentile analysis

Guideline 04-02

EUHA

Europäische Union der
Hörgeräteakustiker e.V.

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Published by Europäische Union der Hörakustiker e.V.
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“Elk test” for percentile analysis

1. Introduction/Aims

The new IEC 60118-15 measurement norm facilitates determining amplification of speech for hearing aids for the setting in which the device is normally worn. The standard describes a test signal, the International Speech Test Signal (ISTS), as well as percentile analysis as a method of evaluation. This paper suggests procedures for testing the implementation of this standard using the test box. This requires a hearing aid set to linear processing, which makes it possible to compare ISTS results with those for sinusoids. Hearing aids with dynamic compression (AGC) and adjustable attack and release times are suitable for further tests.

2. Choosing a hearing aid

Hearing aids with the features mentioned below are suitable for the tests:

- The hearing aid should be operable in a test mode allowing the widest possible frequency range to be set. For volume control, the reference test setting (RTS) must be active, i.e. a setting that results in an average of 77 dB gain below the output level for 90 dB SPL input levels (OSPL90) for frequencies of 1, 1.6, and 2.5 kHz. Dynamic compression (AGC) is set such that its effect is minimal (linear gain) and any adaptive parameters that may affect the measurement of sinusoids (e.g. noise suppression, feedback cancellation, directional microphone) are switched off. The measured gain is also known as reference test gain (RTG).
- The hearing aid should have as short a time delay as possible. This is why analogue devices or digital hearing aids with a small number of channels should be preferred.
- The hearing aid should have at least two acoustic programs and it should be possible to change attack and release times. One of the programs is programmed to short attack and release times. For the other program, acoustic features are to be identical, however, attack and release times should be long.

3. Frequency-dependent gain for sinusoids

To begin with, hearing aid gain is determined for sinusoids in linear setting, and recorded in a corresponding table, or saved to the measurement software as a measuring result. The result will be compared with gain for the ISTS. For a linear hearing aid, both gains must be identical in the mid-level range. Gain for sinusoids can be determined in two ways, via a set of curves, or via the input-output diagram.

3.1 Set of curves

The following procedure is recommended for recording the set of curves:

- The hearing aid is set to RTS (including omnidirectional microphone mode).
- A coupler is used to connect the hearing aid to the measuring microphone (also called coupler microphone).
- The measuring microphone with coupler and reference hearing aid is positioned in the test box together with the reference microphone. The distance between the reference microphone and the microphone of the reference hearing aid (hearing aid microphone) is to be $5 \text{ mm} \pm 3 \text{ mm}$. The hearing aid microphone should be facing the loudspeaker, while the reference microphone is to be placed at a 90-degree angle to that direction (cf. illustration in the Guideline on the practice of calibrating test boxes). None of the two microphones must interfere with the sound incidence from the loudspeaker.
- Sinusoids are presented across the whole frequency range (at least between 200 Hz and 5 kHz) at 50, 60, 70, 80, and 90 dB SPL. The set of curves recorded for output SPLs at the coupler is made up of equally spaced curves (with 10 dB steps) for all frequencies. The 50 dB curve may deviate in the low-frequency range as a result of disturbing noise. Deviations for 80 and 90 dB SPL input levels may be due to saturation effects of the hearing aid and the input SPL. In case the deviations are evident at an input level of 80 dB SPL, using a different type of hearing aid should be considered. The curve resulting at an input level of 90 dB SPL does not correspond to the OSPL90 as the measurement is carried out in RTS rather than with the volume control set to maximum. Apart from the deviations just outlined, when subtracting the steady input SPLs from the frequency-specific OSPLs, the gain curves are identical across frequencies. Gain for several frequencies, e.g. in octave intervals, is recorded in a corresponding table, or saved to the measurement software.

3.2 Input-output diagram (simplified procedure)

This procedure involves recording the curve for one input level, and determining the position of the curves for other input levels via the input-output diagram. We recommend using the procedure that follows:

- The hearing aid is set and positioned as described in 3.1.
- To begin with, a sinusoid is presented across the whole frequency range (at least between 200 Hz and 5 kHz) at 60 dB SPL, resulting in a frequency-specific curve.
- Then the input-output diagram (sound pressure level at the coupler as a function of the input SPL) at 1600 Hz is recorded across the whole input level range (at least between 50 and 80 dB SPL).

- For input levels ranging between 50 and 80 dB SPL, the input-output diagram should exhibit linear behaviour (1:1 slope). When this is true, each input SPL has the same gain. Frequency-specific gain values are again obtained by subtracting 60 dB input SPL from the frequency-specific output SPL recorded at the coupler. As outlined for the set of curves, gain for several frequencies, e.g. in octave intervals, is recorded in a corresponding table, or saved to the measurement software.

In the next sections, we will show how to compare frequency-specific gain for sinusoids, saved as described above, with gain for the ISTS derived by percentile analysis.

We will start by giving an overview of percentile analysis.

4. Overview of percentile analysis

Percentile analysis is used to gain a detailed view of how speech (i.e. the ISTS) is processed by a hearing aid. The results of percentile analysis may be presented in a level frequency diagram as well as in a gain frequency diagram. IEC 60118-15 only outlines the gain frequency diagram. In practice, however, the level frequency diagram is mainly used. Using both types of diagram may lead to misinterpretation of results.

4.1 Level frequency diagram

In fig. 1, the left part shows the input level, the right part the output level as functions of frequency for a random hearing aid setting. The 30th percentile levels equal the lower edge of the blue percentile bars, depicting soft speech portions. The 65th percentile levels shown between the blue and the red percentile bars are located close to the long-term average speech spectrum, LTASS (black line), delineating the average speech level. The

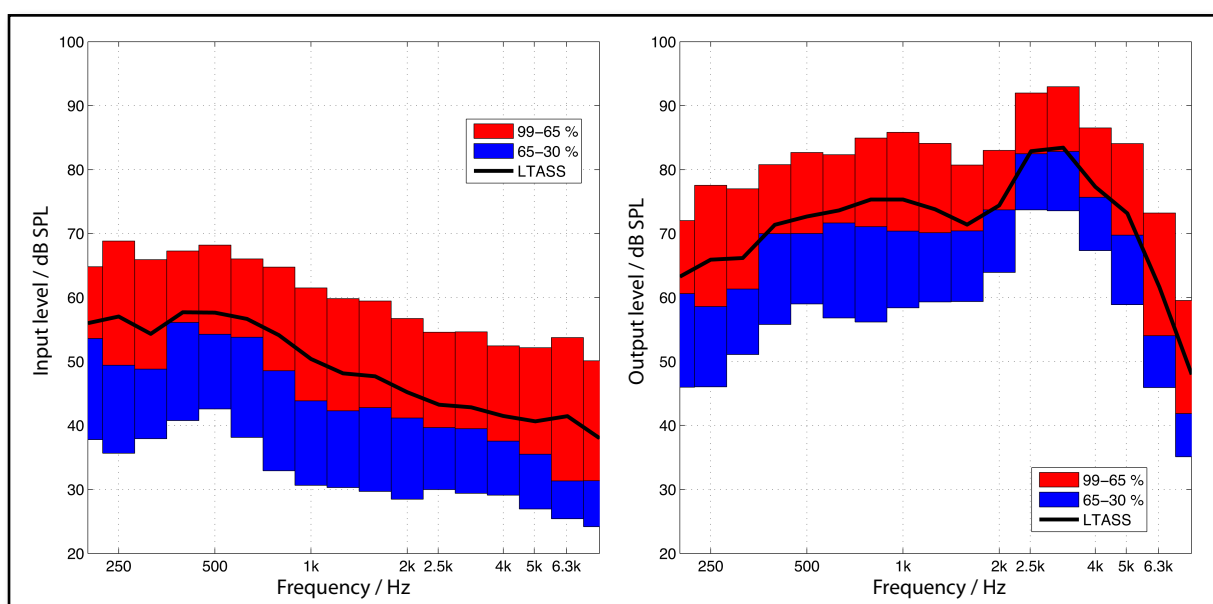


Fig. 1: Level frequency diagrams for the input signal (left) and the output signal (right)

99th percentile levels equal the upper edge of the red percentile bars, depicting the peaks, i.e. the loud speech portions. Alternatively, percentiles may be illustrated using curves rather than bars.

In the level frequency diagram, the 30th percentiles for all frequencies are always located below the 99th percentiles; this applies to input signals as well as to output signals. The 65th percentiles, or the LTASS, are shown between the 30th and the 99th percentiles. If dynamic compression is switched on in the hearing aid – which means that the compression ratio is above 1:1 –, the difference between the 99th and 30th percentiles for the output signal is smaller than that for the input signal, i.e. the percentile bars for the output signal are compressed.

4.2 Gain frequency diagram

The gain frequency diagram (cf. fig. 2) depicts the differences between output and input levels across all frequencies and percentiles, as shown in fig. 1. In contrast to fig. 1, the upper curve shows gain for the 30th percentiles, the curves below that, gain for the 65th percentiles and the LTASS, and the lowest gain curve shows the 99th percentiles. The order just mentioned is based on the fact that higher input levels (and input signal percentiles) result in reduced gain due to dynamic compression.

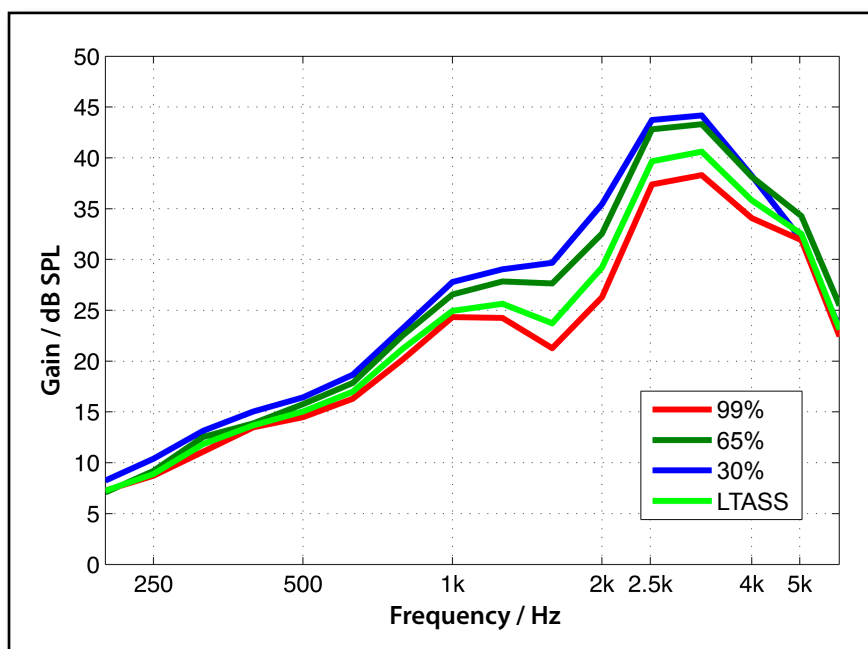


Fig. 2: Gain frequency diagram

5. Verifying percentile analysis

5.1 Gain for ISTS with linear hearing aid

The measurement described below is aimed at verifying if, for a linear hearing aid, the ISTS results in the same amount of gain as the sinusoid (cf. section 3). We will take the following approach:

- The hearing aid is set and positioned as described in 3.1.
- The ISTS is presented for 60 s at 65 dB input SPL.

The measurement result for the ISTS and percentile analysis for a linear hearing aid in RTS should turn out as the gain frequency diagram shown in fig. 3. The three percentiles (30th, 65th, and 99th) and the LTASS overlap as gain remains unchanged in a linear hearing aid.

In the low-frequency range, especially for the 30th percentile, there may be deviations caused by low-frequency noise. This is due to the fact that attenuation in customary test boxes reaches only 2 to approx. 10 dB for the low-frequency range. There may also be deviations in the high-frequency range caused by microphone internal noise. The microphone cartridges of some widely used measuring systems show input internal noise ranging around 30 dB. On the other hand, the ISTS level decreases in the high-frequency range, which means that at 65 dB input SPL, the 30th percentiles may drop below 30 dB. A safe measuring range therefore is between 400 Hz and 5 kHz, which also applies for the 30th percentiles.

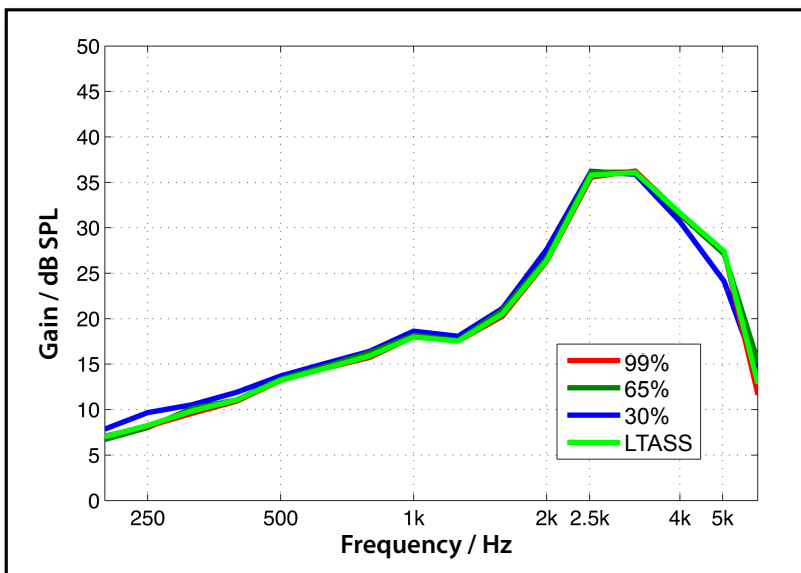


Fig. 3: Gain frequency diagram for the ISTS (linear hearing aid)

Gain values shown in fig. 3 for the ISTS must correspond to the frequency-specific gain values for the sinusoid at 60 or 70 dB input SPL (cf. section 3). In this context, the gain frequency diagram recommended by IEC 60118-15 is more useful than the level frequency diagram.

Should the test box only permit a level frequency diagram (and no gain frequency diagram), one will be provided with a diagram for the ISTS as shown in fig. 4, for instance. In this case, percentile analysis of the output level of the linear hearing aid for the ISTS is shown versus frequency.

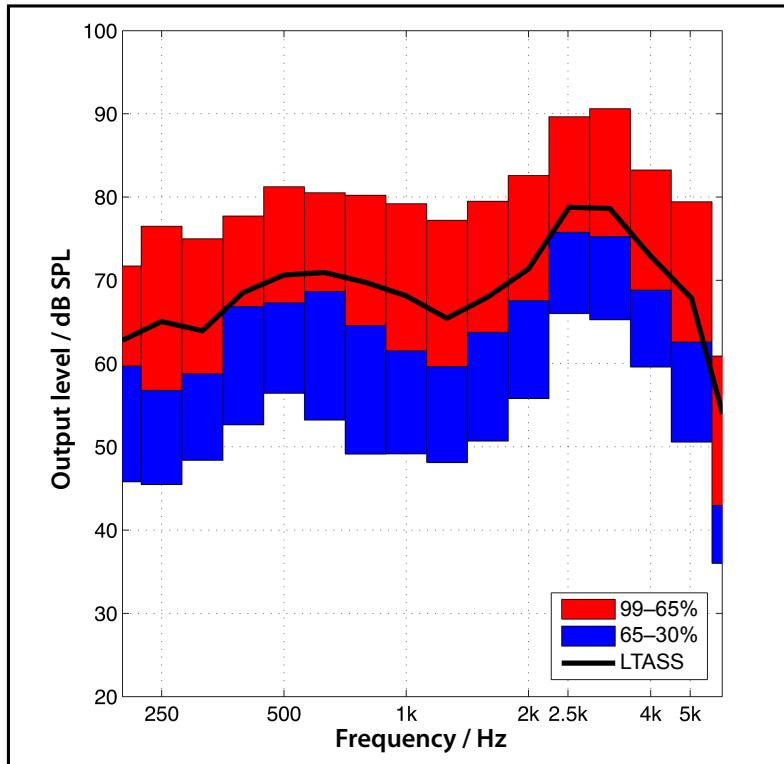


Fig. 4: Output level frequency diagram for the ISTS (linear hearing aid)

The gain frequency diagram may be calculated from the output level frequency diagram by subtracting the values given in table 1 from the output levels. The frequency-specific result must correspond to the frequency-specific gain values for sinusoids at 60 or 70 dB input SPL (cf. section 3).

International Speech Test Signal: Sound pressure levels in dB for third-octave bands (excerpt from IEC 60118-15, simplified)														
kHz	0.25	0.315	0.4	0.5	0.63	0.8	1.0	1.25	1.6	2.0	2.5	3.15	4.0	5.0
99th percentiles	69	66	66	68	67	64	60	59	58	56	54	54	52	51
65th percentiles	48	48	55	53	53	48	44	42	43	41	40	39	37	36
30th percentiles	35	38	41	43	37	33	31	30	30	28	30	28	28	24
LTASS	56	53	57	57	55	53	49	47	47	44	42	42	40	40

Table 1: Input sound pressure levels in dB for third-octave bands

The comparison of sinusoids and ISTS, as described above, is only useful for practical application if performed for the ISTS at 65 dB input SPL. At 50 dB input SPL, disturbing noise and internal microphone noise adversely affect measurements. At 80 dB input SPL, the hearing aid may come close to saturation.

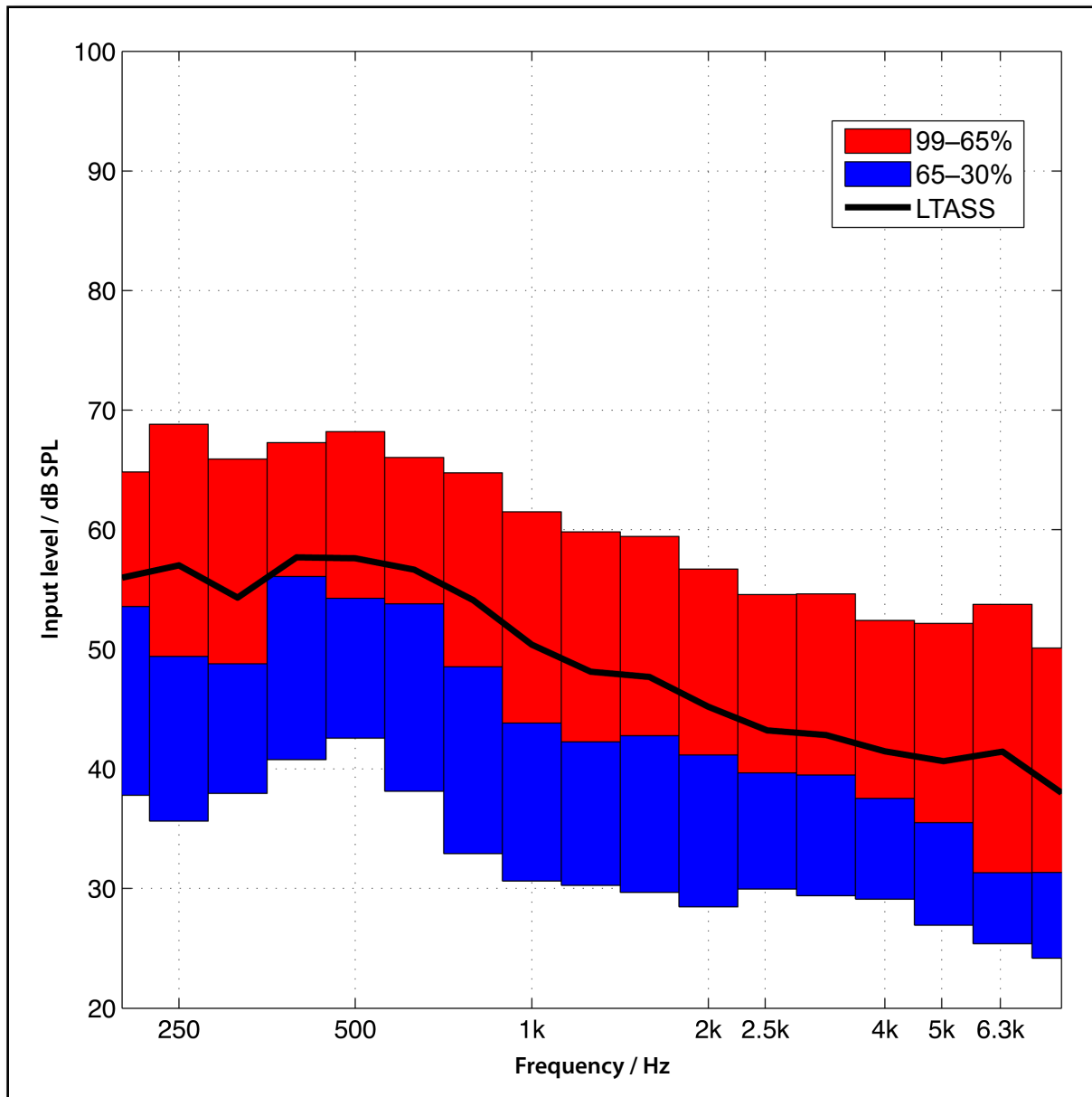


Fig. 5: Diagram of ISTS percentiles corresponding to table 1

5.2 Verifying free-field correction

This test is aimed at verifying if the ISTS is correctly reproduced. Accurate measurements are only possible if the input signal is played back via the speaker at the correct level for all frequency bands. For this reason, the test box speaker has to be corrected for the free field.

To perform this test, the coupler is removed from the measuring microphone; the ISTS is then presented at 65 dB input SPL. Percentile analysis of the output signal at the measuring microphone must correspond to the values given in table 1. These values are also illustrated in fig. 5, which is an enlarged illustration of the input signal shown in fig. 1 (left). Admissible deviation from the values given is ± 3 dB for frequencies ranging between 400 Hz and 5000 Hz.

6. Test with a non-linear hearing aid using ISTS

For a further exploratory assessment, the measuring results may be compared for dynamic compression results with short and long attack and release times. We recommend the following procedure:

- The hearing aid is set to a random setting, e.g. a flat hearing loss of 60 dB HL. All adaptive parameters remain active, however, the microphone is set to omnidirectional.
- All channels are set to compression ratios of 3:1, or higher.
- The two hearing programs should only differ concerning the attack and release times (short or long).
- The hearing aid is connected to the measuring microphone with coupler, and positioned as described in 3.1.
- The ISTS is presented at 65 dB input SPL for 60 s.
- Percentile analysis is performed for the final 45 s of the output signal.

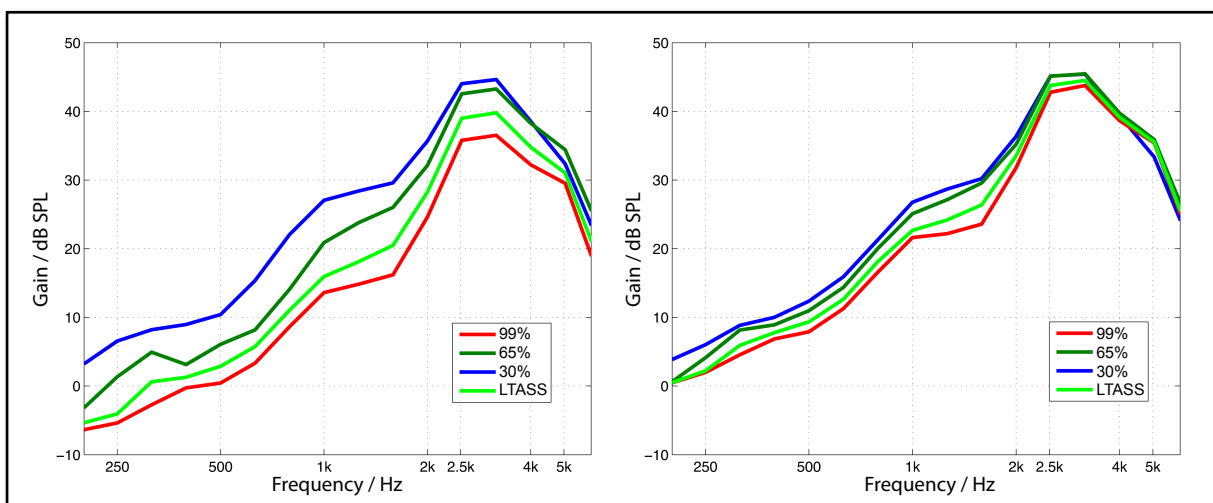


Fig. 6: Gain frequency diagram for the programs with short (left) and with long (right) attack and release times

Fig. 6 (left) shows an example of a gain frequency diagram for short attack and release times (e.g. syllabic compression). As is the case in fig. 2, soft speech portions (30th percentiles) are more amplified than loud speech portions (99th percentiles). This is due to the fact that with short attack and release times, dynamic compression manages to adapt to the speech level variations. The result is quite different for long attack and release times (e.g. automatic volume control, AVC, cf. fig. 6, right). Dynamic compression reacts too slowly to adjust gain to the different speech input levels. This is why all speech portions, as well as all percentiles, are amplified to almost the same degree; percentiles overlap just about as strongly as for a linear hearing aid.

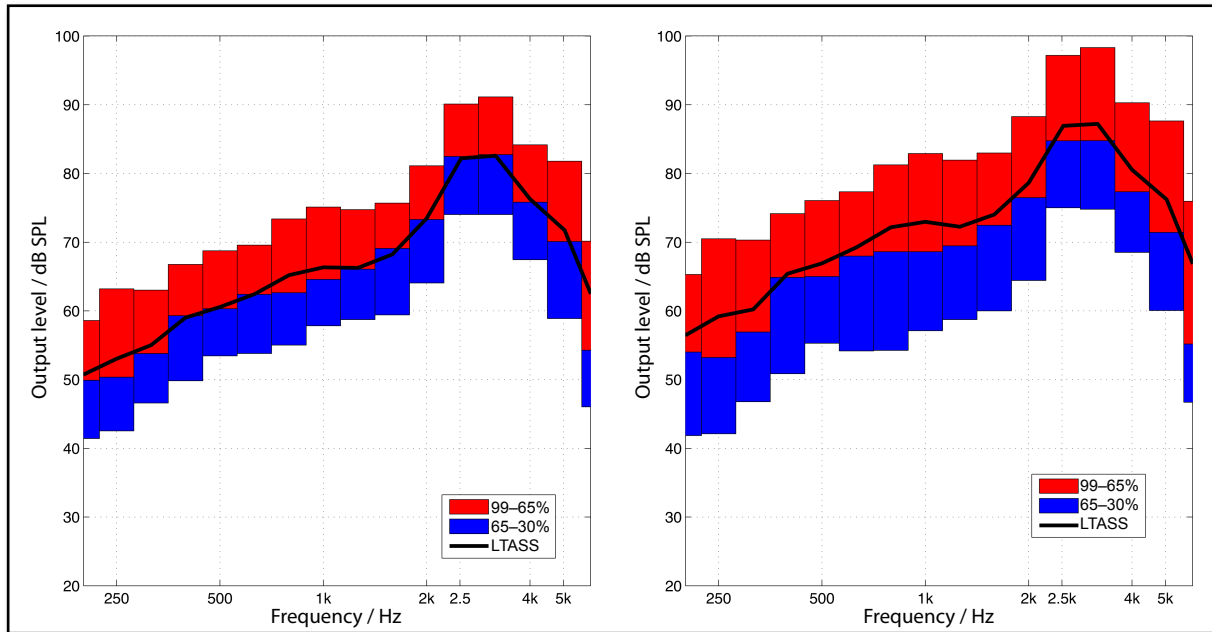


Fig. 7: Level frequency diagram for the programs with short (left) and with long (right) attack and release times

Fig. 7 illustrates the corresponding results for the output level frequency diagram for short (left) and long (right) attack and release times. As described above, here, the upper curve represents the 99th percentiles, whereas the lower curve shows the 30th percentiles. Due to the fast level changes caused by dynamic compression with short attack and release times (cf. fig. 7, left), the 30th percentiles are more amplified than the 99th percentiles, making the difference between the 99th and the 30th percentiles for the output signal smaller than for the input signal. For long attack and release times (cf. fig. 7, right), however, the difference between the 99th and the 30th percentiles for the output signal is all but preserved.