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LOUDNESS METERING: 'EBU MODE' METERING TO SUPPLEMENT EBU R 128 LOUDNESS NORMALIZATION

SUPPLEMENTARY INFORMATION FOR R128

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**Loudness Metering: 'EBU Mode' metering
to supplement Loudness normalisation
in accordance with EBU R 128**

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1.   Introduction

The EBU has studied the needs of audio signal levels in production, distribution and transmission of broadcast programmes. It is of the opinion that an audio-levelling paradigm is needed based on loudness measurement. This is described in EBU Technical Recommendation R 128 [1]. In addition to the average loudness of a programme ('*Programme Loudness*') the EBU recommends that the measures '*Loudness Range*' and '*Maximum True Peak Level*' be used for the normalisation of audio signals and to comply with the technical limits of the complete signal chain as well as the aesthetic needs of each programme/station depending on the genre(s) and the target audience.

In this document the properties of a loudness meter in the so-called **'EBU Mode'** will be introduced and explained in detail. A set of test signals providing minimum requirements for compliance complements the document.

2.   'EBU Mode'

A loudness meter may implement the **'EBU Mode'**. When 'EBU Mode' is activated on a loudness meter, the meter shall comply with the requirements specified in this document (as well as the underlying ITU and EBU recommendations except where differences are explicitly required). Thereby a user could employ loudness meters from different manufacturers with a minimum of confusion caused by differing terminology, scales and measurement methods. A loudness meter may provide alternatives to any or all of the 'EBU Mode' specifications. However, when such alternatives are selected, the meter will no longer be in 'EBU Mode'.

The specification of 'EBU Mode' does *not* concern the graphical/UI details or the implementation of a meter.

The 'EBU Mode' is defined by the parameters described in the following sections.

2.1   The three time scales

Regarding time scales, and their terminology:

1.   The shortest time scale is called 'Momentary', abbreviated '**M**'.
2.   The intermediate time scale is called 'Short-term', abbreviated '**S**'.
3.   The programme- or segment-wise time scale is called 'Integrated', abbreviated '**I**'.

In an 'EBU Mode' 'live meter'[1], all three time scales shall be available, but not necessarily displayed at the same time. A 'non-live' loudness meter, for example a file-based software meter, which only implements a subset of the 'EBU Mode' time scales, is still considered compliant, if that subset complies with the 'EBU Mode' requirements.

The loudness meter shall be able to display the maximum value of the 'Momentary Loudness' and of the 'Short-term Loudness'. These maximum values are reset when the Integrated Loudness measurement is reset.

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[1] A 'live meter' is a meter that can be used in a live environment, measuring an audio signal as it happens. This term is preferable to 'real-time meter' because software analysis of files can be described as 'real-time' or as 'faster than real-time', for example.

2.2 Integration - times and methods, meter ballistics

In all cases the measurement is performed as specified of ITU-R BS.1770 [2].

> *Note:*   *Where the terms "ITU-R BS.1770" and "ITU-R BS.1771" are used, the reader should refer to the most recent versions of the Recommendations published by the ITU-R.*

The measurement parameters for 'EBU Mode' are:

1.   The **Momentary Loudness** uses a sliding rectangular time window of length 0.4 s. The measurement is not gated.
2.   The **Short-term Loudness** uses a sliding rectangular time window of length 3 s. The measurement is not gated. The update rate for 'live meters' shall be at least 10 Hz.
3.   The **Integrated Loudness** uses gating as described in ITU-R BS.1770. The update rate for 'live meters' shall be at least 1 Hz.

Further slowdown of the attack or release (decay) parts of the loudness signals, after the sliding rectangular time windows, shall not be employed in 'EBU Mode' [ITU-R BS.1771-1 prescribes a 1st order IIR filter with a time-constant of 0.4 s to measure Momentary Loudness. However, the EBU has received indications that a time-constant smaller than 0.4 s might be preferable with the IIR method (for example, the meter ballistics would better complement the short-term loudness). Hence the original definition of Momentary Loudness remains in EBU Mode until evidence is available to clarify this issue.].

There may be cases where it is relevant to use other window lengths or time constants than those specified above. This is allowed in a loudness meter offering 'EBU Mode', but it should be clearly indicated on the meter whether or not the set of EBU parameters are in effect ('EBU Mode').

The 'EBU Mode' loudness meter shall at least provide functionality that enables the user to –

1.   <u>start/pause/continue</u> the measurement of Integrated Loudness and Loudness Range simultaneously, that is, switch the meter between 'running' and 'stand-by' states;
2.   <u>reset</u> the measurement of Integrated Loudness and Loudness Range simultaneously, regardless of whether the meter is in the 'running' and 'stand-by' state.

2.3 The measurement gate

The 'Integrated Loudness' shall be measured using the gating function specified in ITU-R BS.1770, summarised as follows:

1.   using an absolute 'silence' gating threshold at **–70 LUFS** for the computation of the absolute-gated loudness level;
2.   using a relative gating threshold, **10 LU** below the absolute-gated loudness level;
3.   The measurement input to which the gating threshold is applied is the loudness of the 400 ms blocks with a constant overlap between consecutive gating blocks of 75%.

If the end of an integrated loudness measurement lies within a gating block, the incomplete gating block shall be discarded.

> *Note:*   *The gating function excludes from the measurement those blocks of audio that are below a threshold. For the relative-threshold based gating function this requires the computation stages described above, as the threshold to be used is itself based on a measurement of loudness. In a live meter the integrated loudness has to be recalculated from the preceding (stored) loudness levels of the blocks from the time the measurement was started, by recalculating the threshold, then applying it to the stored values, every time the meter reading is updated.*

2.4   Loudness Range measure

The measure 'Loudness Range' quantifies the variation in a time-varying loudness measurement; it measures the variation of loudness on a macroscopic timescale. Loudness Range is supplementary to the measure of overall loudness, that is, 'integrated loudness'. The computation of Loudness Range is based on a measurement of loudness level, as specified in ITU-R BS.1770.

The term 'Loudness Range' is abbreviated 'LRA'. LRA is measured in units of '**LU**'. It is noted that 1 LU is equivalent to 1 dB.

An 'EBU Mode' meter shall be able to compute LRA for the audio signal corresponding to the integrated loudness measurement. The LRA computation is reset when the Integrated Loudness measurement is reset.

An 'EBU Mode' meter may be able to turn on and off the display of the Loudness Range.

During the first 60 s of the measurement of LRA (for example, after 'reset') the meter shall indicate that the displayed LRA value is not yet to be considered stable. The individual implementation of the meter may determine the means of providing this indication.

The definition and a reference implementation of the algorithm for calculating 'Loudness Range' are described in EBU Tech 3342 [3].

2.5   Units

The EBU recommends the proposal on naming and units summarized here:

- A *relative* measurement, such as relative to a reference level, or a range: L_K = xx.x **LU**
- An *absolute* measurement, L_K = xx.x **LUFS**
- The 'L' in 'L_K' indicates loudness level, the 'K' indicates the frequency weighting used.

This notation would resolve the inconsistencies currently present in ITU-R BS.1770 and BS.1771 [4], and would moreover make them consistent with other existing standards in that area (ISO, IEC).

> *Note:*   *The proposal on naming and units is described further in the document 'Proposal for the rationalisation of nomenclature used in ITU-R BS.1770 and ITU-R BS.1771', which was submitted by the EBU to the ITU-R in April 2010.*

2.6   True peak measurement

In addition to the specifications of ITU-R BS.1770 Annex 2, the true-peak measure implemented in an 'EBU Mode' meter shall comply with the tolerances specified in Table 1 (signals 15-23), intended as 'minimum requirements' tests. The total measurement error of the true-peak level must comply with these tests, including any pass-band ripple in the upsampling filter and the 'under-read' described in ITU-R BS.1770, Appendix 1 to Annex 2.

2.7   Scales and ranges

The display of an 'EBU Mode' meter may simply be numerical or have an indication on a scale. However, if a scale is shown, it shall meet the following requirements:

An 'EBU Mode' meter shall offer two scales, selectable by the user:

1.   range −18.0 LU to +9.0 LU (−41.0 LUFS to −14.0 LUFS), named '**EBU +9 scale**'
2.   range −36.0 LU to +18.0 LU (−59.0 LUFS to −5.0 LUFS), named '**EBU +18 scale**'

This corresponds to the 'optional' Requirement PLD-4 of ITU-R BS.1771. The 'EBU +9 scale' shall be used by default.

The scale used may either be an absolute scale, using the unit '**LUFS**', or alternatively the zero point may be mapped to some other value, such as the target loudness level (as in ITU-R BS.1771). In the latter case the unit shall be '**LU**', indicating a relative scale. For an 'EBU Mode' meter, the target loudness level shall be **−23.0 LUFS = 0.0 LU** (as defined in EBU R 128). The 'EBU Mode' meter shall offer both the relative and the absolute scale.

The location of the target/reference loudness level shall remain the same, regardless of whether an absolute or relative scale is displayed.

2.8   Display requirements

The physical properties of the loudness meter, such as size, colours, and design, are *not* part of the 'EBU Mode' specification.

A minimum feature set is required for all 'EBU Mode' loudness meters: an 'EBU Mode' compliant meter shall be able to measure and display the three main measures '**Programme Loudness**', '**Loudness Range**' and '**Maximum True Peak Level**'. For 'live meters' these measures need not necessarily be displayed at the same time.

The 'EBU Mode' meter shall use a display precision of at most 1 decimal place in all numerical loudness readouts (Integrated Loudness or Loudness Range, for example).

The display of the Integrated Loudness shall be in units of **LU** or **LUFS**. If absolute and relative scales are switched, the unit of the display of Integrated Loudness shall be switched accordingly. The unit, whether **LUFS** or **LU**, shall be displayed for all values and scales, at all times.

The 'EBU Mode' does not specify what the 'Integrated Loudness' meter should indicate until there is sufficient input data to display a valid result.

The time-scale abbreviations 'M' and 'S' used in this document are the same as those for 'mid' and 'side' in other contexts. Alternatives, for example 'ML$_K$' and 'SL$_K$', have been suggested for use where ambiguity is thought likely.

2.9   Calibration, alignment, compliance and accuracy

Calibration and alignment:

The stereo 1 kHz, 0 dBFS example signal mentioned in ITU-R BS.1770 would be quite loud to listen to. However, the definition of the algorithm means that a given attenuation of the input signal results in the same reduction in the measured result.

For a basic calibration and alignment check of signal level, a 1 kHz stereo sine-wave (signal applied in phase to both channels simultaneously), with its peak level at −18 dBFS, is recommended. The meter should read **−18.0 LUFS**.

The alignment procedure is defined in EBU Tech 3343 '*Guidelines for Production*' [5].

> *Note:*   *A frequency of 1 kHz is used, but as this frequency lies on a filter slope within the algorithm, the calibration is more critical than necessary with respect both to implementation accuracy of the filter and to the accuracy of the calibration frequency. An error in the frequency of the 1 kHz tone can lead to a result different from that expected.*

Minimum requirements, compliance test:

The typical user of an 'EBU Mode' loudness meter will most likely never have the need for performing a compliance test. Thus, a 'minimum requirements' test set is considered sufficient.

If a loudness meter offering 'EBU Mode' does *not* pass these 'minimum requirements' tests and the tests in ITU-R BS.2217-1, there is a considerable risk that the meter is *not* compliant with 'EBU Mode'. If, on the other hand, a meter does pass these tests this does *not* imply that the meter is sufficiently accurate in all respects of its implementation.

Note: *In Report ITU-R BS.2217 [6] the ITU provides a set of test signals and tolerances for the loudness measure of ITU-R BS.1770. The following test signals have been prepared for the benefit of EBU members, to supplement the tests in [6] for 'EBU Mode' meters. However, it should be noted that definitions of compliance tests for the measurement method specified in ITU-R BS.1770 do not, strictly speaking, belong to the scope of this document, and might subsequently be replaced by a corresponding ITU recommendation.*

Table 1: Minimum requirements test signals

Test case	Test signal	Expected response and accepted tolerances
1	Stereo sine wave, 1000 Hz, −23.0 dBFS (per-channel peak level); signal applied in phase to both channels simultaneous; 20 s duration	M, S, I = −23.0 ±0.1 LUFS M, S, I = 0.0 ±0.1 LU
2	As #1 at −33.0 dBFS	M, S, I = −33.0 ±0.1 LUFS M, S, I = −10.0 ±0.1 LU
3	3 tones similar to #1 but with the following durations and levels: [SEP] 10 s at −36.0 dBFS; 60 s at −23.0 dBFS; 10 s at −36.0 dBFS	I = −23.0 ±0.1 LUFS I = 0.0 ±0.1 LU
4	5 tones similar to #1 but with the following durations and levels: [SEP] 10 s at −72.0 dBFS; 10 s at −36.0 dBFS; 60 s at −23.0 dBFS; 10 s at −36.0 dBFS; 10 s at −72.0 dBFS	I = −23.0 ±0.1 LUFS I = 0.0 ±0.1 LU
5	3 tones similar to #1 but with the following durations and levels: [SEP] 20 s at −26.0 dBFS; 20.1 s at −20.0 dBFS; 20 s at −26.0 dBFS	I = −23.0 ±0.1 LUFS I = 0.0 ±0.1 LU

6	5.0 channel sine wave, 1000 Hz, 20 s duration, with per-channel peak levels as follows:
	  −28.0 dBFS in L and R
	  −24.0 dBFS in C
	  −30.0 dBFS in Ls and Rs
		I = −23.0 ±0.1 LUFS
		I = 0.0 ±0.1 LU

7	Authentic programme 1, stereo, narrow loudness range (NLR) programme segment; similar in genre to a commercial/promo	I = −23.0 ±0.1 LUFS I = 0.0 ±0.1 LU
8	Authentic programme 2, stereo, wide loudness range (WLR) programme segment; similar in genre to a movie/drama	I = −23.0 ±0.1 LUFS I = 0.0 ±0.1 LU
9	2 tones similar to #1 but with the following durations and levels: (1.34 s at −20.0 dBFS; 1.66 s at −30.0 dBFS) repeated 5 times	S = −23.0 ±0.1 LUFS, constant after 3 s
10	For file-based meters; 20 segments with tones similar to #1 but with the following durations and levels: (*i* * 0.15 s of silence; 3 s at −23.0 dBFS; 1 s of silence) for *i* = 0, 1, 2, …, 19	Max S = −23.0 ±0.1 LUFS, for each segment
11	For 'live' meters; 20 tones similar to #1 but with the following durations and levels: (*i* * 0.15 s of silence; 3 s at −38.0+*i* dBFS; 3 – *i* * 0.15 s of silence) for *i* = 0, 1, 2, …, 19	Max S = −38.0, −37.0, −36.0, …, −19.0 ±0.1 LUFS, successive values
12	2 tones similar to #1 but with the following durations and levels: (0.18 s at −20.0 dBFS; 0.22 s at −30.0 dBFS) repeated 25 times	M = −23.0 ±0.1 LUFS, constant after 1 s
13	For file-based meters; 20 segments with tones similar to #1 but with the following durations and levels: (*i* * 20 ms of silence; 400 ms at −23.0 dBFS; 1 s of silence) for *i* = 0, 1, 2, …, 19	Max M = −23.0 ±0.1 LUFS, for each segment
14	For 'live' meters; 20 tones similar to #1 but with the following durations and levels: (*i* * 20 ms of silence; 400 ms at −38.0+*i* dBFS; 400 – *i* * 20 ms of silence) for *i* = 0, 1, 2, …, 19	Max M = −38.0, −37.0, −36.0, …, −19.0 ±0.1 LUFS, successive values

15	Stereo sine wave with frequency *fs/4* Hz, amplitude 0.50 FFS[2], phase 0.0 degrees. The frequency *fs/4* denotes 12 kHz for a sample-rate of 48 kHz, etc. The duration of the synthesized tone does not matter, but the tone should be tapered with a 10 ms fade-in and fade–out.	Max. true-peak level = –6.0 +0.2/–0.4 dBTP
16	Stereo sine wave with frequency *fs/4* Hz, amplitude 0.50 FFS, phase 45.0 degrees	Max. true-peak level = –6.0 +0.2/–0.4 dBTP
17	Stereo sine wave with frequency *fs/6* Hz, amplitude 0.50 FFS, phase 60.0 degrees	Max. true-peak level = –6.0 +0.2/–0.4 dBTP
18	Stereo sine wave with frequency *fs/8* Hz, amplitude 0.50 FFS, phase 67.5 degrees	Max. true-peak level = –6.0 +0.2/–0.4 dBTP
19	Stereo sine wave with frequency *fs/4* Hz, amplitude 1.41 FFS, phase 45.0 degrees	Max. true-peak level = +3.0 +0.2/–0.4 dBTP
20	Stereo sine wave with frequency *fs/6* Hz, amplitude 0.50 FFS, containing a single period of a sine wave with frequency *fs/4*, amplitude 1.00; the signal being continuous in phase at both sides of the single period. The signal is synthesized at *4*fs* (for example, 192 kHz), and then lowpass (anti-aliasing) filtered and downsampled to *fs* with a *0* samples offset. The total duration of the synthesized tone does not matter, but the tone should be tapered with a short fade-in and fade–out.	Max. true-peak level = 0.0 +0.2/–0.4 dBTP
21	As #20, but downsampled with a 1 samples offset (at the *4*fs* rate).	Max. true-peak level = 0.0 +0.2/–0.4 dBTP
22	As #20, but downsampled with a 2 samples offset (at the *4*fs* rate).	Max. true-peak level = 0.0 +0.2/–0.4 dBTP
23	As #20, but downsampled with a 3 samples offset (at the *4*fs* rate).	Max. true-peak level = 0.0 +0.2/–0.4 dBTP

The loudness meter shall be reset before each measurement.

Note that test cases 10 and 11 complement each other: As file-based meters can measure a signal with an exact starting time, test 10 is split into 20 different files to be measured individually. In contrast, 'live' meters can perform a real-time measurement with multiple meter readings; hence test 11 consists of one (longer) file that must produce 20 successive values, as specified in Table 1. The same duality applies to test cases 13 and 14.

Warning: Test signals 15-23 are *very* loud and should not be listened to at normal playback levels.

Minimum requirements for test signals for the Loudness Range measure are described more fully in EBU Tech 3342.

These 'minimum requirements test signals' are available for download from the EBU Technical website [7], synthesized at a sampling rate of 48 kHz.

2.10 Various interpretation issues

ITU-R BS.1770 does not include the LFE channel in the measurement. The appropriate gain and frequency-weighting for the LFE channel has been the subject of some discussion and investigation [8]. It is possible that future revisions of ITU-R BS.1770 will take the LFE channel into account.

The EBU recommends that, if the LFE channel were included in the loudness measurement it should be weighted by +10 dB to compensate for the fact that the playback gain of the LFE channel is 10 dB higher in its respective frequency range than the broadband channels ('in-band gain').

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[2] The unit FFS means "fraction full scale".

Until the inclusion of the LFE channel is standardised in ITU-R BS.1770, it shall not be included in an 'EBU Mode' loudness meter. If the LFE is included, then this should be clearly indicated on the meter, since it is not compliant with ITU-R BS.1770, and therefore no longer 'EBU Mode'.

In ITU-R BS.1771, the 'Momentary Loudness' term was adopted by the ITU and *redefined* to use an IIR filter for measurement. Hence measurements of Maximum Momentary Loudness using the 'EBU Mode' definition and using the BS.1771 definition can differ by up to 2 LU.

The 1st order IIR filter employed in measuring the ITU-R BS.1771 definition of 'Momentary Loudness' shall be implemented such that the lowpass filter and its corresponding time-constant applies to the squared samples. Annex 2, p.11 of ITU-R BS.1771 may be misleading in this respect (i.e. it is *not* the output of eq.2 in BS.1770 that is to be filtered).

An 'EBU Mode' meter may optionally display the Momentary Loudness and/or Short-term Loudness of individual channels, in addition to the channel-summed loudness level. The specification of this feature is outside the scope of 'EBU Mode', but any manufacturer implementing it is encouraged to declare which channel-weights are used for the loudness levels displayed for the individual channels.

3.   References

[1]   **EBU R 128**   *'Loudness normalisation and permitted maximum level of audio signals'*

[2]   **ITU-R BS.1770**   *'Algorithms to measure audio programme loudness and true-peak audio level'*

[3]   **EBU Tech 3342**   *'Loudness Range: A measure to supplement loudness normalisation in accordance with EBU R 128'*

[4]   **ITU-R BS.1771**   *'Requirements for loudness and true-peak indicating meters'*

[5]   **EBU Tech 3343**   *'Guidelines for Production of Programmes in accordance with EBU R 128'*

[6]   **ITU-R BS.2217**   *'Compliance material for Recommendation ITU-R BS.1770'*

[7]   **tech.ebu.ch**   *'Minimum requirements test signals for 'EBU Mode' loudness meters'*, available from the EBU at http://tech.ebu.ch/loudness

[8]   **aes.org**   *'Investigations on the Inclusion of the LFE Channel in the ITU-R BS.1770-1 Loudness Algorithm'*, Norcross, Scott G., Lavoie, Michel C.; 127th AES Convention (October 2009) Paper Number: 7829

4.   Further reading

    EBU Tech 3344   *'Guidelines for Distribution and Reproduction of Programmes in accordance with EBU R 128'*