EBU – TECH 3341

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

Supplementary information for R 128

Geneva
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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 descriptors '*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'. This maximum value is reset when the integrated loudness measurement is reset.

2.2 Integration - times and methods, meter ballistics

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

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'. [*Investigation at CBC indicates that a decay time-constant for the momentary loudness would be preferable, however consensus in the EBU has been that the momentary should be more dynamic than QPPM.*]

There may be cases where it is relevant to use other window lengths 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 submitted to the ITU-R for inclusion in the 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, and
2. using a relative gating threshold, 8 **LU** below the absolute-gated loudness level, and
3. the measurement input to which the gating threshold is applied is the loudness of the

[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.

400 ms gating blocks measured using an ITU-R BS.1770 method without gating, that is, summed across channels;

4. a constant overlap between consecutive gating blocks of at least 50% is required (for increased precision especially when measuring programs of short duration).

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

The submission to the ITU-R in October 2010 concerning gating is shown in **Annex 1**.

2.4 Loudness Range descriptor

The descriptor 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.

The definition and a reference implementation of the algorithm for calculating 'Loudness Range' are described in EBU Tech Doc 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: $\mathbf{L_K}$ = xx.x **LU**
- An *absolute* measurement, $\mathbf{L_K}$ = xx.x **LUFS**
- The 'L' in '$\mathbf{L_K}$' indicates loudness level, the 'K' indicates the frequency weighting used.

This notation would resolve the inconsistencies currently present in ITU R BS.1770-1 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 to the ITU-R in April 2010.

2.6 True peak measurement

It is noted that ITU-R BS.1770-1 has optional pre-emphasis and DC blocking for true peak measurement. 'EBU Mode' does not prohibit or require the use of these options. This situation may change and users are advised to check the EBU's website for the most recent version of this EBU Tech Doc.

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: A minor variation of the scale proposed in ITU-R BS.1771 (scale range of 30 **LU**, from -21 **LU** to +9 **LU**) shall be used in 'EBU Mode' meters, with the range -18 **LU** to +9 **LU**. Furthermore, realising that a wider range may be preferable for certain applications, the 'EBU Mode' meter shall also be able to use an alternative scale with double that range.

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 LUFS = 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.

An 'EBU Mode' meter shall offer two scales, for when a scale is shown, 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**'

The 'EBU +9 scale' shall be used by default.

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.

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 peak-level at -18 dBFS, is recommended. The meter should read -18.0 **LUFS**.

The alignment procedure is defined in EBU Tech Doc 3343 '*Practical Guidelines*' [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, there is a considerable risk that the meter is *not* compliant with 'EBU Mode'. If, on the other hand, a meter does pass the 'minimum requirements' tests this does *not* imply that the meter is sufficiently accurate in all respects of its implementation.

Note: *It is anticipated that the ITU might in the future provide definitions of tolerances and test signals for ITU-R BS.1770. Meanwhile, the following test signals have been prepared for the benefit of EBU members. However, it should be noted that definition 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	As #1, preceded by 20 s of -40 dBFS stereo sine wave, and followed by 20 s of -40 dBFS stereo sine wave	**I** = -23.0 ±0.1 **LUFS** **I** = 0.0 ±0.1 **LU**
4	As #3, preceded by 20 s of -75 dBFS stereo sine wave, and followed by 20 s of -75 dBFS stereo sine wave	**I** = -23.0 ±0.1 **LUFS** **I** = 0.0 ±0.1 **LU**
5	As #3, but with the levels of the 3 tones at -26 dBFS, -20 dBFS and -26 dBFS, respectively	**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**

In all the above test cases, the expected response is unchanged if the test signal is repeated one or more times in its full length. The loudness meter shall be reset before each measurement.

Minimum requirements test signals for the Loudness Range descriptor are described more fully in EBU Tech Doc 3342 [3].

These ‘minimum requirements test signals’ [6] are available for download from the EBU Technical website.

2.10 Various interpretation issues

ITU-R BS.1770-1 remains slightly unclear with respect to the summing of loudness across channels. In particular, the text and Figure 1 of Annex 1 do not completely agree, because the figure omits the 10•log10. A Preliminary Draft Revision of BS.1770-1 (given to the EBU for review) shows a corrected figure, however. The summation happens in the squared (power) domain, and the square root of the RMS (i.e., 10•log10) is taken after the summation.

ITU-R BS.1770-1 does not include the LFE channel in the measurement. The appropriate weighting for the LFE channel has been the subject of some discussion and investigation [7]. It is possible that future revisions of ITU-R BS.1770 will take the LFE channel into account. Currently, 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 than the broadband channels. In case the LFE channel is included in the loudness measurements of an ‘EBU Mode’ loudness meter, this should be clearly indicated on the meter, since it is not compliant with ITU-R BS.1770-1.

3. References

[1] **EBU Technical Recommendation R 128** ‘Loudness normalisation and permitted maximum level of audio signals’

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

[3] **EBU Tech Doc 3342** ‘Loudness Range: A descriptor to supplement loudness normalisation in accordance with EBU R 128’

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

[5] **EBU Tech Doc 3343** ‘Practical Guidelines for Production and Implementation in accordance with EBU R 128’

[6] Minimum requirements test signals for ‘EBU Mode’ loudness meters available from the EBU at http://tech.ebu.ch/loudness

[7] ‘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 Doc 3344 ‘Practical Guidelines for Distribution of Programmes in accordance with EBU R 128’

Annex 1: Extract from the EBU submission to ITU-R for the inclusion of Gating in ITU-R BS.1770

The mean square energy of the filtered input signal in a measurement interval T is measured as

$$z_i = \frac{1}{T}\int_0^T y_i^2\,dt \qquad (1)$$

Where y_i is the input signal (filtered by the pre-filter to model head effects, and by the RLB weighting curve), and $i \in I$ where $I = \{L,R,C,Ls,Rs,LFE\}$, the set of input channels.

The loudness over the measurement interval T is defined as

$$\text{Loudness, } L_K = -0.691 + 10\log_{10} \sum_I G_i \cdot z_i \quad \text{LUFS} \qquad (2)$$

where G_i are the weighting coefficients for the individual channels.

To calculate a gated loudness measurement, the interval T is divided into a set of overlapping "gating blocks". A gating block is a set of contiguous audio samples of duration T_g = 400ms, to the nearest sample. The overlap of each gating block to the next shall be equal, shall be at least half of the gating block duration, and be such that

$$\frac{1}{1-overlap} \in \mathbb{N}\backslash\{1\} \qquad (3)$$

where *overlap* is expressed as a fraction of T_g

The measurement interval shall be constrained such that it ends at the end of a gating block. Incomplete gating blocks at the end of the measurement interval are not used.

The mean square energy of the *j*th gating block of the *i*th input channel in the interval T is

$$z_{ij} = \frac{1}{T_g}\int_{T_g \cdot j \cdot step}^{T_g \cdot (j \cdot step + 1)} y_i^2\,dt \qquad \text{where } step = 1\text{-}overlap,$$

$$\text{and} \qquad j \in \left\{0,1,2,\ldots\frac{T - T_g}{T_g \cdot step}\right\} \qquad (4)$$

The *j*th gating block loudness is defined as

$$l_j = -0.691 + 10\log_{10}\sum_i G_i \cdot z_{ij} \qquad (5)$$

For a gating threshold Γ there is a set of gating block indices $J_g = \{j : l_j > \Gamma\}$ where the gating block loudness is above the gating threshold. The number of elements in J_g is $|J_g|$.

The gated loudness of the measurement interval T is then defined as

$$Gated\ loudness, L_{KG} = -0.691 + 10\log_{10}\sum_i G_i \cdot \left(\frac{1}{|J_g|}\cdot\sum_{J_g} z_{ij}\right) LUFS \qquad (6)$$

A two-stage process is used to make a gated measurement, first with an absolute threshold, then with a relative threshold. The relative threshold Γ_r is calculated by measuring the loudness using the absolute threshold, Γ_a = -70 LUFS, and subtracting 8 from the result, thus:

$$\Gamma_r = -0.691 + 10\log_{10}\sum_i G_i \cdot \left(\frac{1}{|J_g|}\cdot\sum_{J_g} z_{ij}\right) - 8LUFS\ ,$$

$$\text{where } J_g = \{j : l_j > \Gamma_a\}, \Gamma_a = -70LUFS \qquad (7)$$

The gated loudness can then be calculated using Γ_r:

$$Gated\ loudness, L_{KG} = -0.691 + 10\log_{10}\sum_i G_i \cdot \left(\frac{1}{|J_g|}\cdot\sum_{J_g} z_{ij}\right) LUFS\ ,$$

$$\text{where } J_g = \{j : l_j > \Gamma_r\} \qquad (8)$$