

# Postprint of Research on Digital Television Program Loudness Standards and Production-End Loudness Control

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**Date:** 2023-10-08T00:00:00+00:00

## Abstract

Digital television programs, featuring high definition and low latency, are capable of delivering superior aesthetic experiences to audiences, thus emerging as a key area of development in recent years. In this paper, the authors begin with the concept of loudness, elucidate the role and significance of loudness in digital television signals, and propose influencing factors and control methodologies for loudness at the production stage of digital television programs by integrating measurement methods and standards for television program loudness. The findings possess certain referential value.

## Full Text

### Preamble

**Title:** Research on Loudness Standards and Production-End Loudness Control for Digital Television Programs

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**Abstract:** Digital television programs, with their high definition and low time delay, can deliver greater aesthetic value to audiences and have thus become a focal point of development in recent years. This paper begins with the concept of loudness, explains the function and significance of digital television signal loudness, and proposes methods for analyzing influencing factors and implementing control at the production end based on television program loudness measurement methods and standards. The findings offer valuable insights for practical application.

**Keywords:** digital television; audio loudness; loudness influencing factors; control methods; audio signals

**Classification:** TN941.2

**Document Code:** A

**Article ID:** 1671-0134(2021)08-146-03

**DOI:** 10.19483/j.cnki.11-4653/n.2021.08.044

**Citation Format:** Zhu Junlan. Research on Loudness Standards and Production-End Loudness Control for Digital Television Programs [J]. China Media Technology, 2021(08): 146-148.

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## 1.1 Concept of Audio Signal Loudness and Influencing Factors

Loudness represents the subjective perception of sound intensity by the human ear and is correlated with signal level, frequency, individual listener characteristics, and listening environment. The primary influencing factors can be categorized into three aspects.

### 1.1.1 Relationship Between Loudness and Frequency

Loudness is frequency-dependent. Most television audio professionals are familiar with the relationship between loudness and frequency: the human ear perceives different frequencies with varying loudness sensitivity. For pure-tone signals that are subjectively equal in loudness level, the sound pressure level differs if the frequency varies. The equal-loudness contour diagram clearly illustrates that under different frequency conditions, different sound pressure levels are required to achieve the same perceived loudness. The relationship between loudness and frequency is shown in Figure 1 [Figure 1: see original paper].

**Figure 1:** Standard equal-loudness contours for pure tones

### 1.1.2 Relationship Between Loudness and Signal Level

From an acoustical perspective, loudness bears a logarithmic relationship to sound pressure. For identical signals, loudness increases as sound pressure level rises. Therefore, under the same playback conditions for a given audio signal, increasing the signal level raises the reproduced sound pressure level. However, while loudness reflects subjective auditory perception, signal level is an objective physical quantity. Signals at identical levels but different frequencies may produce different loudness perceptions. Consequently, for the same audio signal, level and loudness are positively correlated: increasing level raises loudness [?].

### 1.1.3 Relationship Between Loudness and Time

Loudness is also related to sound duration. Auditory perception exhibits memory characteristics, and test results demonstrate that within a duration range of 100ms-200ms, loudness increases with longer signal duration. Therefore, both

the continuous length or density of program audio and the signal' s electrical level value simultaneously influence the program' s overall loudness.

Based on the above analysis, loudness is a physical quantity tied to subjective evaluation, comprehensively influenced by factors including source signal level, source frequency, transmission equipment, and playback devices.

## 1.2 Impact of Digital Television Program Loudness on Programs and Audiences

Television program audio signals are ultimately transmitted to the receiving end, where audiences make subjective assessments of picture and sound quality. If the average loudness of digital television programs from different sources or genres maintains moderate consistency, audiences can better enjoy the content. When switching between different channels or program types, their psychological perception of loudness remains constant without discomfort caused by significant fluctuations. Conversely, inconsistent loudness forces viewers to constantly adjust volume when watching different programs or switching channels, negatively impacting the viewing experience.

Furthermore, during program exchange across different media, discrepancies in loudness and level standards require amplitude processing during signal uploading, which can affect dynamic range and signal-to-noise ratio. Achieving moderately consistent average loudness across production, broadcasting, and distribution stages would facilitate usage for diverse users while ensuring uniform sound quality and volume, thereby improving audience satisfaction.

The role of loudness for audiences becomes clear through the standard-setting process. According to relevant documentation, the following tests were conducted to establish China' s digital program average loudness standard: First, an audio workstation played a 1 kHz monophonic test signal at -24 dBFS loudness, with output gain adjusted to produce a reproduced sound pressure level of 60 dB SPL. Test program signals were then played with unchanged output gain, while the workstation adjusted program audio gain to produce reproduced sound pressure levels ranging from 50 dBA SPL to 80 dBA SPL, creating seven test sequences played in random order to evaluators. Subjective evaluation results indicated 65 dBA as the most appropriate level. Based on test system calibration results and gain compensation, the corresponding audio signal loudness yielded a most comfortable loudness value of -23 LKFS, 1 LU higher than the standard-specified target value for digital television program average loudness [?]. After comprehensive consideration of international program exchange standards, the final specification was set at -24 dBFS  $\pm$  2 LU (dB).

## 2.1 Calculation Methods for Audio Signal Loudness

The most widely applied loudness algorithm is the ITU-R BS.1770 series for measuring audio program loudness and true-peak audio levels. This algorithm simu-

lates human loudness perception using a cascade of two second-order filters. The resulting frequency response curve after filtering is termed “K-weighting,” which exhibits trends opposite to both equal-loudness contours and the A-weighting curve based on them. Audio signals pass through a pre-filter and leq(RLB) filter weighting, with the calculated weighted root-mean-square level representing program loudness. The absolute loudness unit is LKFS [?].

## 2.2 Loudness Measurement for Digital Television Signals

Since digital television signals may include mono, stereo, and surround sound formats, algorithms applicable to loudness measurement of mono, stereo, and multichannel audio signals are required. When measuring multichannel signal loudness, the process mirrors monophonic loudness algorithms: each channel undergoes “K” frequency weighting, followed by calculation of each channel’s energy root-mean-square value, then weighted summation across channels to provide a composite loudness measurement.

**Figure 2 [Figure 2: see original paper]:** Flowchart of multichannel audio signal loudness measurement algorithm

Based on human auditory characteristics, sounds arriving from behind a listener are perceived as louder than those from the front. Therefore, weighting coefficients differ across channels when calculating multichannel signal loudness, with surround channels receiving higher weights and excluding the LFE channel.

**Table 1 :** Weighting coefficients for audio channels

## 2.3 Standards for Digital Television Program Loudness

According to the *Technical Requirements for Average Loudness and True-Peak Audio Level of Digital Television Programs* (GY/T 282-2014), this standard applies to production, broadcasting, and distribution stages of digital television programs. Technical requirements specify:

1. Program loudness shall be measured per GY/T 262, including all audio channels (up to 5 channels, excluding the low-frequency effects channel).
2. Average loudness shall be measured across the complete program duration.
3. The target value for digital television program average loudness shall be -24 LKFS.
4. The tolerance range for the average loudness target value shall be  $\pm 2$  LU. Average loudness values from an institution (channel) shall not remain consistently at the upper or lower edges of this tolerance range.
5. If metadata is used to indicate program average loudness, the metadata value shall correspond to the average loudness across the entire program duration.
6. The maximum true-peak audio level across the entire program shall not exceed -2 dB TP [?].

### 3. Analysis of Influencing Factors and Control Methods at the Digital Television Program Production End

Effective loudness control for digital television programs requires proper regulation during the production stage, as this represents the program source. Only by controlling source signal loudness can receiving-end audio quality be ensured. Production-stage loudness control necessitates analysis of influencing factors to propose targeted control methods.

#### 3.1 Real-Time Broadcast Automatic Loudness Control Methods

For live programs, loudness fluctuations caused by non-uniform signal sources and dynamic studio conditions must be adjusted in real time during broadcasting. Failure to do so results in non-compliant broadcast loudness and volume variations. Traditionally, audio engineers perform manual volume control during live broadcasts, calibrating through standard monitoring to maintain loudness within reasonable ranges. However, this approach cannot react promptly to sudden volume changes. In television station automatic broadcasting systems, compressors or limiters are typically employed to restrict peak signal levels, preventing overload distortion. Yet as previously analyzed, level control alone does not necessarily alter loudness. Real-time loudness control during broadcasting is required to achieve compliance with GY/T 282-2014 standards. Therefore, practical implementation necessitates incorporating loudness control equipment into the broadcast chain to perform signal-level automatic loudness correction in real time according to preset parameters and strategies, enabling automatic monitoring and recording of loudness metrics.

While this approach can instantaneously adjust broadcast loudness, several issues exist. First, adding real-time loudness monitoring and adjustment equipment introduces delay, typically causing audio lag of several tens of milliseconds, which not only violates regulatory technical standards but also creates audiovisual synchronization issues for viewers, requiring additional delay units to compensate. Second, real-time loudness control can only simply reduce loudness in 超标 (non-compliant) segments without adjusting other segments according to program content, causing overall dynamic range loss and degraded broadcast audio quality. Consequently, real-time loudness control is primarily suitable for live broadcast segments and generally not recommended for recorded programs.

#### 3.2 Using Loudness Meters and Non-Linear Editing Software for Post-Production Loudness Control

During digital television program production, loudness meters are appropriate tools for monitoring audio signals. Dragon TV currently uses RTW hardware loudness meters for surround sound program production, controlling the loudness center reading at -24 LKFS during mixing to achieve overall program loudness control. However, due to high hardware costs and the predominant use of Pro Tools non-linear software for post-production audio, software plugin loud-

ness meters are often selected. Currently, TC and Waves loudness meters are most commonly used—the former offering rich functionality, the latter being economical and practical. Both enable real-time loudness supervision and logging during mixing while recording overall program loudness conditions to facilitate adjustments by production staff.

**Figure 3 [Figure 3: see original paper]:** Interface of Waves loudness meter plugin

Using Waves loudness meter as an example, it complies with ITU 1770-3, EBU, and ATSC standards, monitoring Momentary, Short-Term, Long-Term loudness, and True Peak levels. It includes alarm and logging systems that track level data and provide real-time alerts when values exceed or fall below specified ranges. Gain and trim controls enable loudness normalization and correction when necessary. The meter supports mono, stereo, 5.0-channel, and 5.1-channel formats, monitoring not only loudness but also instantaneous peak levels via true-peak metering. For Long-Term loudness applications, per ITU 1770-3 standards, the average loudness during continuous 30-minute playback should be approximately -24 dB LKFS, providing a convenient parameter for overall television program loudness control that meets daily production requirements.

Selecting appropriate loudness meter monitoring software during post-production enables control of program audio signal loudness while preserving dynamic effects and achieving favorable signal-to-noise ratios, representing the preferred production workflow.

### 3.3 Monitoring and Adjusting Uploaded Programs

During broadcasting, programs uploaded to the broadcast system originate from diverse sources, requiring unified loudness for program audio signals. For instance, rebroadcasting earlier programs produced without loudness standards results in significant perceptual differences, while programs exchanged with online media often exceed broadcasting standards due to differing loudness specifications. Uniform adjustment of various programs is therefore prerequisite for consistent broadcast signal loudness, necessitating loudness meter review during pre-broadcast technical examination to meet national broadcasting standards.

The program upload stage is suitable for file-based loudness control processing. First, loudness analysis of the file obtains the source file's loudness, then program level is shifted according to target values to achieve compliance. During this shifting process, target value and limit level settings are critical, as overall level shifting may cause signal overload, requiring reasonable protection values. For programs carrying metadata, target loudness adjustment can be conveniently performed. Since audio metadata carries parameters including audio production information, mixing levels, dynamic range control, channel modes, downmix control, and dialogue levels, metadata technology enables loudness regulation based on level parameters and dynamic range. This technology has not yet been widely adopted and requires further popularization.

## Conclusion

Digital television programs, with advantages including high definition, low distortion, minimal interference, and wide signal amplitude, have gradually replaced traditional analog television signals and achieved widespread application. Digital television program production must ensure both excellent picture quality and audio control, as superior audio characteristics combined with high-definition visuals deliver ideal viewing experiences. This paper examined the concept of loudness in digital television programs, analyzing definitions, audience responses to program loudness, and China's digital television program production loudness specifications. It investigated measurement methods including relevant ITU standards, relationships between loudness and level values, and calculation methods for digital television audio signal loudness. Based on these standards, the paper proposed production-end loudness influencing factor analysis and control methods, including real-time broadcast automatic loudness control, post-production loudness control using NLE software plugins, and loudness control during program upload. These approaches preserve favorable program dynamics and audio quality, delivering excellent audio-visual experiences to television audiences. The proposed methods have proven effective through engineering practice and can serve as valuable references and theoretical guidance for relevant technical professionals.

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*Note: Figure translations are in progress. See original paper for figures.*

*Source: ChinaXiv –Machine translation. Verify with original.*