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A Preliminary Study of Television Program Loudness Monitoring Systems (Postprint)

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Abstract

This paper presents the definition of television program audio loudness and industry standard requirements, provides a detailed analysis of the existing controversies regarding television program loudness in China, and proposes a feasible design for a television program loudness monitoring system.

Full Text

Preliminary Study on Television Program Loudness Monitoring Systems

Authors: Sun Yabin, Wang Peng

Abstract: This paper introduces the definition of television program audio loudness and relevant industry standards, analyzes specific issues currently existing in Chinese television program loudness, and proposes a feasible design for a television program loudness monitoring system.

Given the numerous and complex stages of television program production, broadcasting, transmission, reception, and playback, audio loudness control has long been a challenging problem in the television industry. Volume jumps frequently occur not only between different television channels but also during program transitions within the same channel, significantly impacting and causing discomfort for viewers. Therefore, it is imperative for broadcast monitoring and regulatory authorities to include television program loudness within their monitoring scope.

1. Definition and Standards of Loudness

Loudness is generally defined as the subjective human perception of sound intensity. Multiple factors influence perceived loudness, including the electrical

level of television program audio signals, sound frequency, and program dynamic range. Traditionally, audio systems have relied on measuring signal level to reflect loudness, commonly using VU and PPM meters. VU meters measure quasi-average signal levels, displaying level changes through rapid pointer movement, but this introduces response delays that prevent the display of subtle level fluctuations. PPM meters measure quasi-peak levels, primarily showing current peak conditions. However, since it is typically impossible to sample precisely at the exact moment a true peak signal occurs, sampled peak levels cannot accurately indicate true peak levels.

Since loudness cannot be characterized by level alone, the International Telecommunication Union (ITU) proposed an algorithm for measuring audio program loudness and true peak audio level in the ITU-R BS.1770 series recommendations, aiming to objectively describe human perception of sound intensity. This algorithm applies a pre-filter that simulates the acoustic effect of the human head and a Leq(RLB) weighting filter in cascade to audio signals. The resulting weighted mean-square level represents program loudness, with the absolute loudness unit being LKFS (Loudness, K-weighted, relative to full scale) [1]. LKFS is equivalent to the LUFS (Loudness units relative to full scale) unit proposed in the European Broadcasting Union's EBU R128 recommendation, which also defines the relative loudness unit as LU (Loudness units). Additionally, true peak level is measured through proportional oversampling and high-frequency pre-emphasis of audio signals, yielding more precise decibel measurements relative to 100% full scale, expressed in dB TP.

According to China's specific circumstances, the National Press and Publication Administration's GY/T 282-2014 "Technical Requirements for Average Loudness and True Peak Audio Level of Digital Television Programs" explicitly stipulates that the average loudness target value for digital television programs should be –24LKFS$±$2LU, and the maximum true peak audio level for the entire program should not exceed –2dB TP [2].

2. Causes of Loudness Differences

Regarding their impact on television program audio loudness, the entire transmission chain can be broadly divided into three domains: program production/broadcast, signal transmission, and user reception. The following sections provide specific analysis of loudness difference issues in each process.

2.1 Program Production/Broadcast Domain

When loudness differences exist between programs on a television channel, they predominantly originate in the production and broadcast stages. First, programs aired on the same channel come from diverse production sources that may not uniformly adopt loudness-based measurement and control equipment during production and broadcasting, resulting in significant variations. Second, different program types and content requirements necessitate correspond-

ing changes in audio dynamic range during production, where programs with smaller dynamic ranges exhibit higher perceived loudness. Furthermore, certain advertisements and television shopping programs intentionally increase loudness relative to regular programs to attract viewer attention, representing the most prominent aspect of current loudness issues. In practice, the strategy of boosting program loudness during production no longer provides any advantage in broadcast environments, as programs exceeding loudness thresholds undergo signal compression during loudness control, causing audible quality degradation. Consequently, in today's pursuit of high-fidelity audio, gaining perceptual advantage through increased loudness has become increasingly unimportant for television programs and may even prove counterproductive.

2.2 Signal Transmission Domain

Although encoding and scrambling operations occur in the signal transmission domain, they essentially do not alter program content but may affect program audio signal level. Therefore, for the same program, the transmission domain's impact on loudness primarily manifests as changes to audio signal level. Even when uniform standards are applied during production and broadcast, achieving compliant average loudness and maximum true peak levels, final loudness may still vary due to different transmission link gains across channels. Common sources of gain in the signal transmission domain include:

2.2.1 Link Gain from Level Mismatch During Analog-to-Digital Conversion During analog-to-digital conversion of program audio signals, incorrect correspondence between digital and analog full-scale levels in conversion equipment introduces gain. The most common level errors occur in encoder stages.

2.2.2 Link Gain from Manual Adjustments at Different Transmission Nodes Audio signal levels can be manually adjusted at various transmission nodes, including playout control, transmission stations, satellite uplinks, and cable headends. Inappropriate manual adjustments to program audio signal levels introduce link gain.

2.2.3 Link Gain from Analog Device Impedance Mismatch Due to limitations in China's television industry development, the entire television network has not yet achieved complete digitization, with analog devices still employed in certain links. Failure to ensure proper impedance matching between analog and digital devices can elevate analog program audio signal levels, thereby introducing gain in the transmission link [3].

2.3 User Reception Domain

Beyond program production and transmission, audio signals undergo further processing in user reception environments, which can be categorized into sev-

eral types. Professional-grade high-fidelity cinema systems achieve the most accurate signal reproduction, faithfully preserving original quality. Most viewers, however, rely on television speakers, which offer relatively inferior performance. Additionally, some audiences use mobile devices, headphones, or Bluetooth speakers to play television audio. These differences at the terminal end of the television transmission chain create certain difficulties in maintaining loudness consistency.

3. System Design

Chinese television programs, particularly advertisements, frequently exhibit audio loudness significantly exceeding that of regular programs, severely impacting viewer experience and hindering industry development. To standardize television program audio loudness, we must continue prioritizing loudness monitoring and regulation, integrate audio loudness into the regulatory framework, and establish comprehensive monitoring systems to enable timely detection and handling of non-compliant loudness practices.

3.1 Functional Concept

Loudness monitoring equipment primarily processes incoming TS streams, decodes corresponding audio files through analysis, and calculates accurate loudness values using standardized algorithms. The equipment supports stable 7$×$24 operation. The system retains audio files for a minimum of 30 days, with non-compliant program audio files archived long-term. Monitoring results data are also preserved long-term.

Loudness monitoring data processing software implements alarm threshold configuration based on GY/T 282-2014 specifications, where program average loudness target value is –24LKFS with a tolerance of $±$2LU. The software classifies and statistically analyzes measured loudness values, generating corresponding report data. It also processes large volumes of data for alarming, statistical analysis, and graphical visualization.

3.2 System Architecture

The “Audio Acquisition” module obtains audio data from external TS streams. The loudness monitoring backend service stores this audio in the storage system according to design principles. During storage, audio is indexed by timestamp to facilitate retrieval by the “Loudness Calculation” module for specific time periods. Since different television channels have varying transmission paths and processing units entering the “Audio Acquisition” module, resulting in different delays, careful alignment with program playback and storage timing is required in system implementation.

The “Loudness Calculation” module reads corresponding audio from the “Audio Storage System” based on input program duration, performs loudness calcula-

tions, submits results to the "Business Logic" module, and saves data to the database.

The "Fixed-Duration Program Division" module divides television channels into fixed-duration "programs" in the absence of precise program schedules, submitting each program's start and end times to the Loudness Calculation module.

The "Audio Storage Management" module periodically cleans expired audio data and transfers audio from programs exceeding threshold values to evidence storage for long-term retention. Assuming a program audio bitrate of 300 kbps, storing audio for one television channel requires 3.24 GB per day; considering that precise program schedules may only become available after 24 hours, storing three days of audio for one channel requires 9.72 GB.

The "Program Schedule Acquisition" module obtains precise program schedules through various channels: (1) from television stations for previous-day broadcasts, or (2) from the regulatory center's database for already-cataloged channel schedules. This module converts schedules obtained from different sources into start and end times for use by the "Loudness Calculation" module interface and drives the calculation process.

The "Business Logic" module receives program loudness calculation results submitted by the "Loudness Calculation" module, stores them in the database, and generates real-time or periodic loudness reports based on configured conditions for use by the "Business Presentation" module.

References

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