Loudness Normalization under Consideration of the Loudness Range (LRA)

(Lautheitsnormalisierung unter Berücksichtigung der Loudness Range (LRA))

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Abstract

The Loudness Range (LRA), defined in EBU R 128, proved to be a very practical measure for continuous automatic loudness normalization while largely preserving the original dynamic properties of an audio signal. Furthermore, it appears to be very suitable for the detection and elimination of intra-program loudness jumps. The paper shows the relationship between Program Loudness and Loudness Range. After illustrating the algorithm needed for calculating the Loudness Range, the resulting value is interpreted. Here, the acoustic difference between microdynamics and macrodynamics is highlighted, as well as the methods and consequences of their technical alteration. On this basis, a real time method is described, which, by using the Loudness Range, continuously adapts Program Loudness and thereby preserves the original loudness dynamic or deliberately changes it. After the differentiation of desired and random dynamics a consistent loudness concept is presented, taking the Loudness Range into account, as it is already implemented within pilot projects of German broadcasters. In this respect, experiences from the implementation process are illustrated and discussed.

1. Introduction

In the following, the EBU specific measurement Loudness Range (LRA) will be considered closely and its ratio to loudness will be discussed.

Loudness Range is an additional measurement of the EBU, which describes the change in loudness within a program equivalent to the dynamic performance of loudness. As the loudness within a program is only defined for a whole program but not for an audio section, the LRA calculation is based on the mean of a short timed sequence. The duration of this chosen time intervall has a crucial impact on the interpretation because the interpreter has to dinstinguish between micro- and macrodynamic.

2. The Loudness Range Measurement Based on EBU R128

2.1. Algorithm Description

The Loudness Range, defined in EBU R 128, measures the macrodynamic of an audio signal [1]. The short timed loudness is determined by three seconds long and overlapping sequences according to the Short-Term-Loudness measurement. The loudness difference between the highest 5% and the lowest 10% of the measurement defines the Loudness Range in loudness units (LU) (see figure 1). Short-Term-values that are filtered out through a gating-mechanism in several steps, are not included in the measurement. Therefore the algorithm doesn´t recognize silent passages or background noise, consequently it becomes more stable in practice. The Loudness Range as a statistical size increases its reliability with the number of measured values. So LRA with a duration less than 30 seconds suits the results only in a limited way.

The EBU standardized a characteristic variable of macrodynamic with the above mentioned definition which has a direct relation to loudness. The algorithm, developed by TC Electronic, has been available open source and unpatented for the EBU since 2009 and has been included as an official part in EBU R 128 as the accompanying document Tech 3342. In comparison to loudness, the Loudness Range is not standardized at ITU.

The LRA was evaluated during the PLOUD-workingprocesses carefully and discussed by plenty of examples. Unfortunately, no credible psychoacoustical research has been conducted so far, that investigated the direct relation between the Loudness Range and the subjectively perceived loudness fluctuations of a program. However, many practical experiences and the knowledge exist allowing the assumption that a practical connection for most of the broadcast signals is suitable.

The Loudness Range is not an appropiate size in order to detect hypercompression. But many hypercompressed music pieces show a small macrodynamic and thus a lower LRA-value.

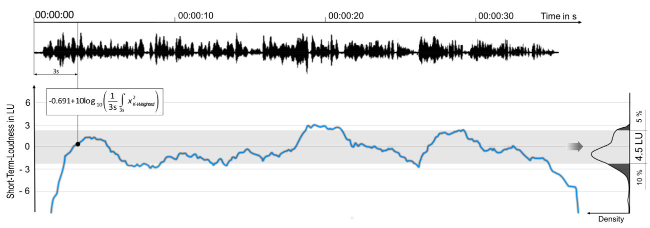

Fig. 1: LRA-measurement in a systematic depiction.

2.2. LRA-Value Interpretation

Microdynamic Microdynamic describes the loudness ratio of short and successive sequences, for example the energetic ratio of successive speech sounds (word accent). In music, it characterises the ratio of attack energy to the tone (accent). Quite short attack and release time is chosen in a compander-system in order to change the microdynamic.

In speech signals for instance, the microdynamic is perceived slightly and thus unappropriately changed as "pump". Though calm speech naturally shows a dynamic difference between breath and starting speech sound clearly. Unappropriate compression decreases this difference essentially and thus the speech becomes anxious. As a stylistic tool it is legimitate. In order to maintain a transparent audio transfer this unappropriate compression is not desired though.

The hypercompression found the focus of attention during the loudness war and is usually realised using Brickwall-limiters (e.g. Sequoia - sMax11). The loudness war means the competition of the energy maximum in signals within the limits regarding distribution paths (peak level normalisation). Brickwall-limiters have a short attack- and release-time (1-2ms). The dynamic changes are shorter than single speech sounds or single hits and therefore almost impossible to be perceived. But the sound changes with every control event because of the comparably high frequency modulation of the signal intervention and this may result in distortion. The more often and stronger signals are controlled, the greater the changes in sounds are. If the signal is controlled as strong as the limiter reduces the level for every syllable or every single hit, not only the sound but also the microdynamic pattern changes. The reason for this is the energy of the loudest sequence of the signal which reaches a constant maximum. When the gain is increased for the whole signal, lower sequences can only be turned up in volume resulting in a decrease of the energy difference between single sequences. Thus the microdynamic becomes lower and unnatural.

Macrodynamic Macrodynamic describes the energy ratio in longer sequences. For instance, it gives information about the change in energy within one or more spoken sentences or the change in the dynamic within several bars in music (e.g. crescendo or the contrast of piano and forte). Macrodynamic influences the accent of a sentence in speech and sometimes also of more sentences.

It is possible that macrodynamic is produced undesired and from the content's point of view is created by record and broadcasting systems randomly.

A high macrodynamic means a unique demand for the reproduction system and the listening environment. However, content including a small macrodynamic are intelligible everywhere but may sound boring after a while.

Desired Macrodynamic An artistic meaning has an important value for the desired macrodynamic in order to express the content in an authentic way. In speech, the meaning finds its use to stress certain sentences or words and highlight their content or create tension. Also in music the desired macrodynamic is a common stylistic tool.

A speech contribution with an informative character shows a lower macrodynamic in tendency compared to an artistic speech contribution. Furthermore audience in a cinema or classical concert experiences a high macrodynamic which makes an essential part in this event.

Wether a signal, distributed in a certain way, is able to be sent and available for recipients in terms of its macrodynamical characteristics, can be estimated by the LRA algorithm.

Random Macrodynamic Commonly this kind of macrodynamic appears because of different adjusted levels. If two parts of the programme with different recorded levels are played after each other without the averaged loudness to be adjusted, it is called "loudnessjump". The loudness jump produces dynamic. But listeners usually perceive this dynamic as unpleasant because no connection exists to the content.

Furthermore, random dynamic can also arise from a bad recording situation. Which dynamic is desired or accidental can only be concluded out of the context.

In order to save the consumer from using the remote control, different signal levels in broadcasting have to be corrected manually. Especially this means an enormous challenge in broadcasting caused by the increasing number of self-op programs.

Manual changes can be avoided from a technical perspective. This is based on an appropriate measurement method to determine the loudness and the Loudness Range. Thus, successive parts of a program should be reproduced with the same loudness unless the producer desires to create dynamic.

3. LRA Opportunities in Practice

3.1. Loudness Normalization in Real-Time under Maintenance of the Original Dynamic Characteristics

The measurement duration of loudness, defined in EBU R 128 orientates itself towards the length of the editing program. This file-based way of thinking results in enormous problems for the loudness control in real-time without considering any additional sizes for the loudness dynamic. On the one hand the goal is the leveling of the averaged loudness of the signal in order to apply loudness processors in real-time. On the other hand the reduction of undesired loudness jumps is wanted. Although the term "loudnessjump" let somebody assume that phenomena are described by the EBU-loudness, this term means the short-time, macrodynamic changes in the audio signal. Therefore one solution to fall back on different processors is to conduct the measurement and leveling in comparitively short time frames. If this process is realised not only by a simple automatic gain control (AGC) but a multi-step control process, a reduction of loudness jumps can be achieved. It is problematic though that firstly the natural loudness dynamic of the incoming signal is undetectable because an appropriate measurement method is lacking. Secondly, every longer deviation of the Short-Term-Loudness from the set loudness value will be detected and corrected. Consequently, big changes in the original loudness course and thus in the loudness dynamic may arise that are undesired in practice. Figure 2 shows the original course of a test signal's Short-Term-Loudness (blue graph) and the loudness course of the same signal after editing with a proprietary loudness processoring that includes a short control constant (red graph). The change in the original loudness course by the processor can be recognized well.

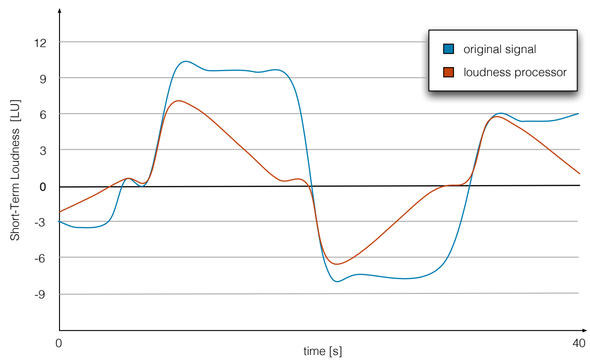

Fig. 2: Change in the loudness dynamic by a loudness processor.

The concept of a loudness control considering the Loudness Range, thus including a measurement for the perceived dynamic of a signal, is in contrast to the above explained process. The goal is to realize a non-destructive loudness control by recognizing the incoming signal's natural loudness dynamic. A technical process is therefore used that is able this way to detect the loudness dynamic in real-time and to control the averaged loudness and the loudness dynamic seperately. The averaged loudness is calculated for a limited time frame but for the whole program as it is done in a real-time process in general. This sequence is marked as long as a gain adjustment does not lead to a subjective audible change. This process corresponds to the sound engineer's work as the sound engineer aims to reach the chosen loudness value by correcting the sum of the mixer for a longer time period. On the other hand loudness jumps can be retained in the original material or can be reduced in a precisely defined amount by determining a maximum for the Loudness Range. Figure 3 shows this process and the loudness course of the edited signal (green) that matches the course of the incoming signal (blue). But the transition from loud parts to quiet parts and the transition reversely is less drastical. Thus, the LRA control in the real-time loudness processor is bascially used to detect a signal's natural loudness dynamic and to preserve it as good as possible. Secondary, annoying loudness jumps can be reduced to a precisely defined fluctuation area.

3.2. Outgoing Signal Adjustment to the Dynamical Requirements of Different Buses

It is desirable to adjust the subjectively audible dynamic to the requirements of each listener's reproduction situation in order to achieve the best possible listening experience. For example, only a small loudness dynamic is practical in a driving car until quiet parts are masked by the high environmental noise or until loud parts can become a dangerous distraction. But the situation in a living room at home is completely different. This is why the consumer should know about the transmitted

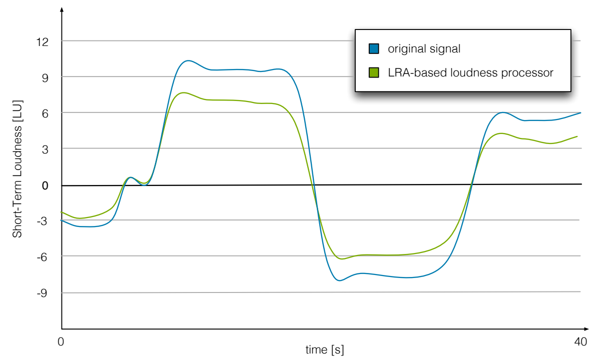

Fig. 3: Control of loudness and loudness dynamic by a LRA-based loudness processor.

dynamic ideally. Although it is possible to conclude the most frequent listening environment according to airtime, content of the program and transmission channel. For instance, VHF-transmission is assoziated with radios in citchens and in cars during rushhours essentially whereas the transmission via satellite has the image of good listening conditions such as HiFi. Based on this assumption an effective adjustment of the loudness dynamic can be made individually on every bus in the distribution step. The LRA control is very useful for this adjustment because it has to intervene into with the signal way less audible than a common compression in order to get the same result in the dynamic reduction. In addition a LRA real-time control can be realized quite easily because no additional effort in production and broadcasting has to be done. An automatic adjustment of the dynamic ratio is even better tunable directly in the receiver. But the technology available for this has not proved itself in practice yet.

3.3. Loudness Range to Ensure Quality

The first pilot projects with Westdeutscher Rundfunk and Südwestrundfunk showed that the Loudness Range, as an quality ensuring and objective characteristic, suits to evaluate the production quality. Broadcast programs are produced more and more by journalists or video cutter without any sound engineering background and with just a very limited time permitted. Therfore a lot of received contributions include undesired and unavoidable loudness jumps. A higher LRA-value is an indicator for such mistakes in the productions especially in formats in the fields of news production. A useful action includes the signal control and program correction as soon as a particular treshold is exceeded. The LRA adjustment realizes the correction in which the microdynamical characteristics of the signal remain. If the contribution is already disposed to transmission, it passes the quality backup without any edition in order to avoid any time problems in the broadcast plan.

Recordingsystems and audio-editing-software should already support journalists as early and simple as possible in controlling and adjusting loudness and loudness dynamic. A very easy and safe adjustment of the loudness parameter is possible during the edition phase in which a contribution is created out of seperate original sounds, moderations and other elements. In this phase the contribution may still be judged creatively.

4. "Real LRA-Control" versus Compression

4.1. Qualitative Meaning of Technical Processes to the LRA-Adjustment

The technical realization should be done with a special attention because it means an irreversible and non-standardized interference into the audio signal in contrast to an loudness adjustment. The audible consequences in the dynamic edition is caused more often by the edition process than by the actual dynamic reduction. This is why various devices have a different, characteristic sound in connection to compressors. The LRA-adjustment is the most important qualitative differentiation-charactersitic within file-based tools besides the real-time processors to the loudness adjustments and Loudness Range adjustment, which generally use very different and proprietary algorithms.

4.2. LRA-Adjustment Compressors

Peak-level-compressors are regularly used in manual LRA-edition as well as in different software solutions. This kind of audio compressors owns a snapped-off characteristic as shown in figure 4 and thus reduces the amplitude of signals high-levelled peaks. The whole capacity change in the audio signal has to occur in the peak level area. This change may lead to a reduction of the Loudness Range. Consequently, signal transients have to be edited extremely and the subjective signal sensitivity changes clearly Also this kind of audio compressors lead to a strong distortion of the peak statistic and thus the result is a change in the original short loudness course as shown in figure 5.

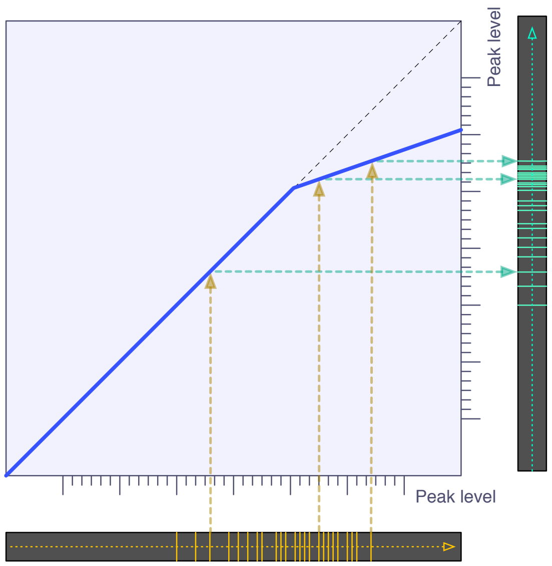

Fig. 4: Characteristic curve of a peak level compressor and its influence on a signal's level statistic.

But compressors with a linear characteristic curve (figure 6), that are moved from a certain point, work much better for the LRA-adjustment. Thus, the characteristic curve's slope matches the compression ratio. If the audio signal's loudness of the program is used as a point, the loudness area is reduced

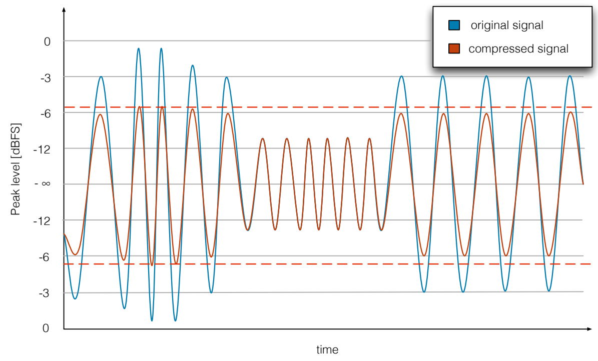

Fig. 5: Fixed limitation of signal peaks made by compression.

symmatrically close to the loudness value. The original and short loudness course as well as the dynamical arc of suspense desired from the sound engineer remain preserved by this way and both are only shortened with a chosen factor (see also figure 3). Compared to the peak-level-compression, the compression method described in this paragraph has another benefit: it comes towards the technical procedure of the LRA-measurement and thus enables an effective LRA-reduction using a much smaller compression ratio.

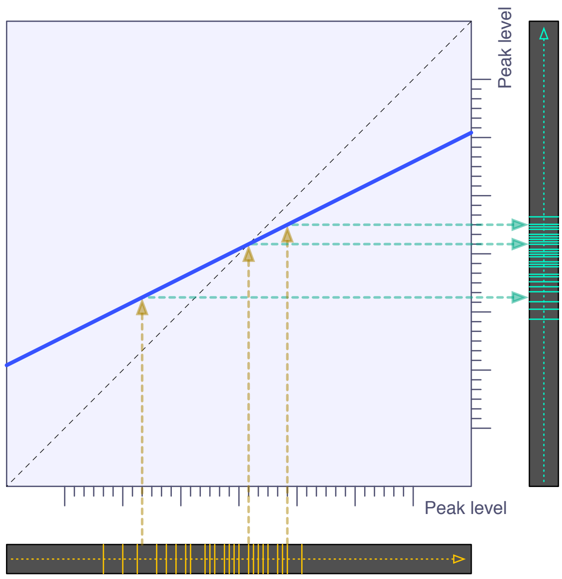

Fig. 6: A linear compressor's characteristic curve and its influence on the peak statistic.

If a LRA-adjustment is done with conventional compression procedures, it is usually realized by using a control loop. The schematical description in figure 7 shows, that the incoming signal is first edited with random compressor-parameters. Also it shows the parameter setting which is optimized through a postswitched LRA-measurement for a certain time frame and a control loop belonging to the measurement until the system reaches the desired LRA-maximum. Dynamical and technically similar procedures are not only used in real-time-adjustement of the LRA but also in the file based edition because it is rarely practical to process a program with statical compressor properties. The desired averaged LRA-value would be achieved then but longer sequences with low or high loudness-fluctuations would be edited too much or just a little. The result would be subjectively unsatisfied. A time leveling of the compressor‘s characteristic curve using the described backwards control is also quite easy to realize technically because the complicated, non-linear connection between incoming level, parameter setting of the compressor and resulting LRA may be unknown. This process leads to the biggest disadvantage in practice though: a backwards control without any direct relation between edition process and LRA-result is always too slow because the measured sequence has already passed the time frame and cannot be edited anymore. A following sequence will be changed instead that may have different dynamical characteristics. Thus, no satisfying limitation of the subjectively perceived dynamic can be achieved in some cases with audio signals including a signal characteristic that varies in time much.

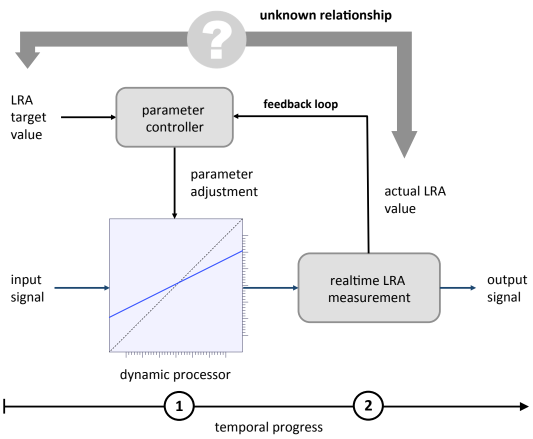

Fig. 7: Schematical setup of a LRA-control with backwards control.

5. “Real LRA-Control”

The use of a “real LRS-control” enables the opportunity to achieve the best possible LRA-adjustment including the change in the signal to be as small as possible apart from conventional compression procedures. Such a procedure is characterized by acting mostly deterministically regarding the LRA. Thus, the final LRA-value can be concluded from its historical development, the current incoming audio signal as well as the parameter setting of the algorithm (see figure 8). Such an onward control of the LRA ensures that each sequence of the program is limited in its loudness dynamic through time correctly. Consequently, it also ensures that the desired, audible loudness fluctuation is not exceeded. Therefore, an editing procedure is required that measures weighted power values internally according to the EBU-Loudness but amplitude values compared to compressors. As shown in figure 9, another benefit is that such a system does not detect any signal peaks, also it hardly edits peaks. So transients and the signal‘s microdynamic remain preserved. Real-time-processing as well as file-based LRA-adjustment benefit from a “real LRA-control” considering the first described disadvantages of the backwards control.

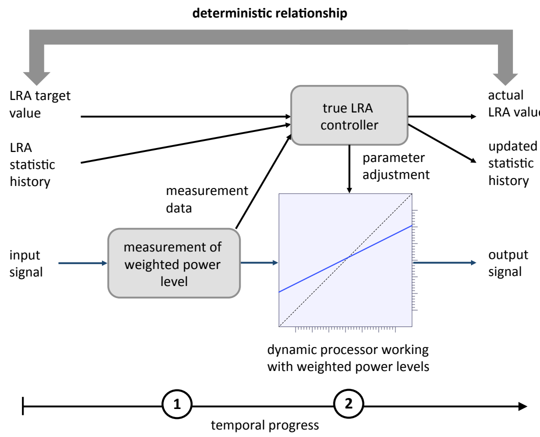

Fig. 8: Schematical setup of a “real LRA-control” with a known connection between LRA-traget-value and LRA-value after edition.

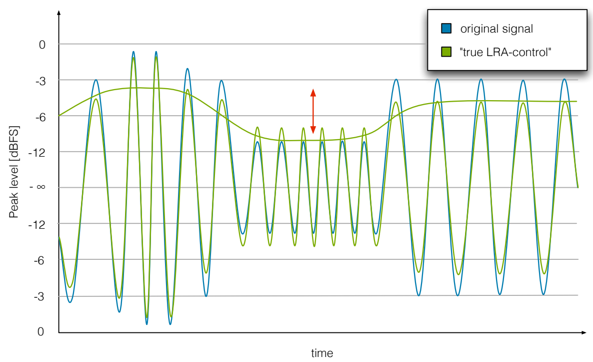

Fig. 9: The “real LRA-control” does not detect and edit seperate peak values but only the power course of the signal.

5.1. Time Characteristics of Dynamic Edition Processes

Furthermore, time characteristics of the signal processes are very important for the qualitative systems evaluation. The more adaptive a dynamic edition process is able to integrate to the time change of the incoming signal the less compression artefacts, e.g. “pumping”, is expected. Hereby, most systems differ enormously.

5.2. Resolution Update in the Public Radio Broadcasting in Germany

The ARD (Consortium of public broadcasters in Germany) radio broadcasting is convinced of the substantial benefits when it comes to the EBU-Loudness-control. The editorial and technical responsible committees passed a concept according to the EBU-Loudness-control. In comparison to the realization in television the radio broadcasting is more focused on supporting moderators in the self-op operation as well as a better intelligibility of a program. This is supposed to be done by reducing “random macrodynamic” which is caused by controlling parts of the program wrongly. An adjustment of different waves in broadcasting to a standard emission loudness is not planned to prevent the analogue distribution channels from loosing their listeners.

5.3. Outlining a Consistent Loudness Concept in the Radio Broadcasting

Westdeutscher Rundfunk (WDR) research revealed that changing the production operations in the radio broadcasting to a loudness based control enables a broadcast operation without loudness jumps. Therefore all real-time and filebased sources including microfone channels as well as conference and telefonbroadcasts have to be loudness-normalized and free of random dynamic at the input of the broadcast mixer. Then the channels are only added and muted without any level adjustments.

This way a transmission of the outgoing signal is possible without any further dynamic editions for some distribution paths. Thus, the receiver quality for the listener equals almost the production quality. The whole audiotechnical quality of the programs increases at the same time because important and dynamical characteristics of music can remain preserved.

The daily radio broadcasting practice shows that it is almost not possible to send a higher dynamic using the current technical opportunities without dealing with a high number of loudness jumps. On the one hand high dynamical, cultural programs are unavoidable, on the other hand information and service programs limit their dynamic much using voice and transmission processes. But even the reduction does not always work because the applied AGC has often to run with compromised properties.

The qualitively best results are achieved with the manual loudness control by the sound engineer in this environment. This task cannot be realized in the self-op operations personally but it can be solved with good results applying an automatic loudness processing. Thereby, a combination of filebased systems in the production and broadcast planning as well as real-time systems in the area of broadcast studios are brought in ideally.

Distribution paths, e.g. VHF, that have to be limited in its loudness dynamic because of the inconvenient reproduction conditions should be optimized in the distribution step with a "real LRA-control" instead of a common AGC.

The WDR investigations could also show that this kind of edited signal does not lead to any tonal change in the soundprocessing. This fact enables a successive change of all distribution path individually without causing additional effort in the broadcast operations.

A multiplex limiter remains necessary for the VHF-distribution-path for legal reasons. In this case the targeted loudness value should be chosen sufficiently low in order to prevent the sound from any changes by the limiter.

5.4. Summary

This article showed that the Loudness Range as a measurement size and an edition basis means an essential element in a consistent loudness concept of the broadcasting. As a size for the natural dynamic of a processing program it can help to improve a loudness adjustment in real-time enormously. If the program is longer, it can also enhance a file-based loudness adjustment. The Loudness Range is also suited to optimize the dynamical loudness scope of different distribution paths. The edited signal makes a profit from the LRA-algorithm optimized for the macrodynamic measurement because it enables a better maintenance of the signal's quality compared to conventional processes of dynamic edition. Furthermore, the Loudness Range measurement could prove practically to be an important characteristic for processing the quality evaluation automatically. Investigations in cooperation with the Westdeutscher Rundfunk showed that the loudness control with regard to the LRA can be used profitably. Also the loudness control can be implemented into the excisting, technical infrastructur with a manageable effort.