TECHNICAL PAPER

Toward a Recommendation for a European Standard of Peak and LKFS Loudness Levels

By E.M. Grimm, R. van Everdingen, and M. J. L. C. Schöpping

Complaints about loudness variations between program items are a well-known issue in television broadcasting worldwide. The cause is found in the replacement of skilled operators by automated broadcast systems. To facilitate automated leveling of program items, the International Telecommunications Union Recommendations Section (ITU-R) has published recommendation BS-1770, introducing the LKFS loudness measurement. The broadcaster's goal is uniform dynamics; thus a standardized loudness level needs to be accompanied by a standardized peak level. Most stations in Europe use the European Broadcasting Union (EBU's) PPM standard of -9 dBFS, and any new standard should be compatible with this. The analog PPM falls short in indicating fast (digital) peaks. These do, however, add to the perceived dynamic range, or rather the loudness-to-peak ratio (LPR). An additional digital peak standard is therefore needed before an LKFS level can be selected. Our research into the level practice of 50 international television stations suggests setting maximum digital sample peak levels to -5 dBFS and nominal loudness levels to -21 LKFS.

INTRODUCTION

The current ITU-R BS.645-2 recommendation for broadcast levels[1] only specifies PPM[2] peak levels. To harmonize loudness levels between programs, PPM measurements fall short. European broadcasters are therefore in need of a new recommendation that includes loudness levels, preferably from the EBU. The new LKFS measurement, introduced in the ITU BS.1770 recommendation,[3] is recognized as a very good candidate. LKFS is short for "Loudness, K-weighted, relative to Full Scale." It is similar to well-known Leq measurements, but with a different weighting curve. To provide recommendations on the standard maximum LKFS level, research into the use of loudness-to-peak ratio by 50 television stations was performed. It turned out that any recommendation on maximum LKFS level should be accompanied by an advice on maximum digital sample peak (or preferably true peak) level also.

BACKGROUND

Loudness differences between programs and stations are a well-known issue.[4-9] The main cause is that operators are being phased out in favor of automated playout and human level control is lacking in modern facilities. Another cause in The Netherlands is that Dutch stations have adopted a policy of transmitting material without alteration. The reason for this is that in 1999 an advertiser consulted an engineering agency to perform level measurements on commercial blocks. It turned out there were differences in peak (PPM) levels between what the advertiser had submitted and what was transmitted.[10] The advertiser threatened to withdraw if the station changed its commercial levels again. The station were only allowed to check compliance with the ITU/EBU recommendation, which solely addresses max PPM levels.[1] Loudness is determined by average energy, not by peaks, so loudness can vary considerably among programs with equal peak levels. As a result of the new policy, viewers started complaining that commercials were too loud. Because riding levels was no longer an option, the only way out was to raise the level of normal program material by means of general dynamics compression. This appeared to partially solve the problem, because programs such as a documentary with dialog recorded in a market square lose intelligibility as a result of compression much sooner than close microphone commercial voiceovers. A compromise setting of the compressor was found. Viewer complaints were reduced, but did not vanish. The new setting, however, did lead to complaints by directors and engineers of drama and documentary films, because it had a negative effect on their artistic mix balance choices and caused loss of dramatic impact by compromising deliberate level differences.

In May 2005, the VCA, a society of Dutch Film Sound Engineers,[11] organized a "Television Broadcast Loudness Symposium"[12] in The Netherlands that was attended by representatives of all relevant fields: engineers and managers of public and commercial broadcast stations, post-production houses and distribution companies, as well as producers and directors of commercials, dramas, and documentaries. Attendees of the symposium agreed that the current situation was unfavorable. Producers of commercials also agreed that they were longing for the artistic options that the dynamic use of sound level offer (e.g., in drama productions). Currently, they are forced to use heavy compression; if not, the clip will be too low against the competition in a commercial block. Distribution companies experienced a different problem, in which they must

combine the levels of several stations in a manner that viewers can switch between channels without large sound level differences. Broadcasters began developing automated systems for gradually leveling loudness differences and longed for a standard for loudness measurement.

As a result, a Dutch Broadcasting Loudness Committee was formed, on which the authors of this paper participate, along with representatives of public and commercial stations and post-production houses. Their task was to research a means for leveling program material while preserving artistic choices. An addition to the current audio levels standard—incorporating a loudness level measurement—was soon found to be necessary. International harmonization for this measurement was seen as mandatory and cooperation with ITU's SRG3 group began. Their BS.1770 LKFS loudness measurement[3] appeared to be perfectly suitable for Dutch program material and led to better consistency in program loudness levels than the overall dynamics processing currently in use.[13] Other authors reported similar results for other countries.[14]

Loudness-to-Peak Ratio

When the time came to implement BS.1770, the committee faced a complicated challenge. Setting a target loudness level makes sense only in its relation to a peak level. There is demand for both uniform loudness levels and enough loudness-to-peak range (LPR). The LPR is the difference between the average LKFS loudness level and the maximum true peak level (as defined in ITU BS.1771).[15] Different environments have different LPR demands. The LPR preferred in a movie theater is approximately 6 to 7 dB higher than the optimum for a domestic environment.[16,17] Thus, once the maximum digital peak level is set, the loudness level can be chosen accordingly.

The problem encountered was that although PPM levels are standardized in the European Union (EU), digital peak levels are not. The EBU recommends 0 PPM to be aligned to -9 dBFS,[18] the PPM meter having attack ballistics of 10 ms.[2] However, on digital peak levels[18] the EBU states that "due to the characteristics of quasi-peak program meters used by broadcasters, the true program peaks can be 3 dB greater than those indicated. When operator errors are taken into account, the true peaks may occasionally be 6 dB greater than indicated." Digital peaks above -9 dBFS are mentioned, but there is no official limit to the maximum digital peak level in this recommendation.

The use of very fast look-ahead "brick wall" limiters has become the practice in many broadcast stations. In the days of analog on-air transmission, these were used to limit the deviation and corresponding bandwidth of the transmitter. The lack of an indication for maximum levels in the EBU recommendation[18] has probably led to confusion about the level at which this brick wall limiter should begin working. This, in spite of the PAL B/G standard of ITU-R[19] and its European adaptations such as CENELEC EN50083-5.[20] These clearly advise alignment of 0 PPM to 30 kHz FM deviation, which is 4.4 dB below the allowed maximum peak level. Some stations (e.g., national German stations) followed the standard and had their limiters set accordingly to approximately -4.5 dBFS. Some have interpreted the EBU recommendation[18] and ITU-R recommendation[1] such that "no signal may exceed -9 dBFS."[21] Because operators often monitor on PPM's referring to the ITU-R recommendation,[1] this last situation unfortunately leads to quite severe peak limiting.

The transition from analog on-air transmission of television stations to digital distribution has led to the situation in which analog RF modulation adjustments are only performed at transmission facilities for cable television. Here dozens of local, national, and international channels, with audio sources varying from terrestrial and satellite reception to direct studio links are prepared for delivery. This is done so that viewers do not experience large-level jumps when switching channels. Most distribution companies do not want to interfere with the dynamics chosen by stations, so the loudness level of the channel with the smallest LPR is attenuated to match that of the channel with the largest LPR. Modern technology such as LKFS-based automatic level control systems[22] are installed in some cable head-ends, and recently even audio level control directly in MPEG streams (without decoding and recoding) was introduced to facilitate leveling in DVB links.[23] Of course, these systems cannot accommodate level differences within one channel, so they only minimize level changes between channels.

Consequently, for broadcasting stations, the choices in types of processing in the transmission chain will not influence the relative loudness of the station on a viewer's television (like it did in the on-air transmission days). It will change only the available dynamic range for program material and thus the sound quality. Stations with a smaller LPR just end up peaking at lower levels in the viewer's television than stations with higher LPR. This is confirmed by measurement done by the authors. Very fast peak limiting to avoid overload of analog RF modulators, therefore, makes little sense when combined with dynamics compression.

SURVEY OF CURRENT LEVELS

As mentioned earlier, an LKFS-based maximum loudness level seems to be the appropriate choice in use of dynamics to solve the annoying level differences among programs while preserving the director's artistic choices. However, before a standard LKFS level can be selected for EU broadcast stations, a consensus is needed as far as the maximum allowed digital peak level. It is recommended the old ITU-R recommendation[1] be retained and a new recommendation for both maximum digital peak level and maximum LKFS level be added.

The authors decided to perform a survey on current digital peak, PPM, and LKFS levels in Europe. Based on this knowledge, a proper choice can be made in selecting the right maximum levels for digital peaks and LKFS. In our opinion any new standard recommendation should comply with daily practice as seamlessly as possible.

Survey Design

To have an objective view of current practice, one needs access to raw transmissions of many stations. Reception from analog cable delivery was ruled out because of distribution companies' interference with levels. Digital television reception presented the best compromise. Although some stations are known to process their DVB feeds differently from their direct feeds to analog transmitters and distribution companies, on average, this provides a representative view. Fifty international stations were selected (**Table 1**). The channels were received through Dutch distribution companies REKAM and CAIW. These companies use satellite links mostly for reception of foreign stations; the latter, however, also uses direct studio feeds for national and local stations. REKAM provides a level transparent link; CAIW utilizes the new ITNM Systems ALC system to losslessly control gain directly in MPEG streams.[23] The ALC levels were known to the authors, so the measurements could be corrected accordingly. Of the stations, 46% were Dutch, as a result of the goals of the Dutch Broadcasting Loudness Committee. This left 27 channels of foreign origin, with 24 EU stations (apart from the Dutch). This was reasonably representative of the European situation.

The authors chose not to anonymize the names of the stations in the paper because the study has prompted discussion about practical implementation of LKFS and peak level standards. Thus, it is important to consider everyone's position in this debate. The intention here is not to reveal "bad" behavior. Every station had valid professional grounds to set the levels they chose.

Instead of analyzing just a few channels, the authors chose to make an analysis of many channels. This provided a broader view that seemed advantageous. A few different programs were recorded on several days for every channel, each fragment being about 6 min in length. The digital peaks were measured using the internal meters of the Adobe Audition software used for recording. These are sample peak levels, not true peak levels, as recommended in ITU-R Rec. BS.1771.[15] PPM levels were measured using a calibrated DK Audio MSD100. LKFS levels were measured using a dedicated piece of software, developed at the Utrecht School of Music Technology by Wouter Snel at al.[13] This software fully complies with BS.1770.

RESULTS AND ANALYSIS

In **Fig. 1**, the levels of all measurements are gathered. These are the exact levels received, without any normalization. Maximum LKFS is plot in blue, maximum PPM in yellow, and maximum digital sample peak in red. The LKFS levels in **Fig. 1** show very large loudness differences among channels. These are the levels as transmitted by the stations, without interference from distribution companies. On analog cable reception, the level differences are potentially smaller because of the controlling levels of distribution companies. The measurements show the level selection of the stations themselves, as received by distribution companies. The most extreme loudness difference is between Het Gesprek (-29 LKFS) and NET5 (-13 LKFS): a jump of 16 dB in loudness! One step better still shows 9 dB in loudness difference: BBC2 (-24 LKFS) versus SBS6 (-15 dBFS). It is clear that if stations do not harmonize their levels, distribution companies will have to do it for them. As mentioned earlier, some stations have chosen to set their brick wall limiters to a threshold of -9 dBFS. These can be easily tracked in **Fig. 1**; approximately 22% of the measured stations limit to -9 dBFS +/- 1 dB.

Another interesting element found in **Fig. 1** is that many stations do not comply with ITU-R BS.645-2.[1] Only 40% of the stations peak within 1 dB of 0 PPM, 34% peak too high, and 22% peak too low. Two stations were kept out of these percentages because of inconsistency in their broadcasts, sometimes peaking 9 dB low, sometimes 3 dB loud. The EBU recommendation is followed by less than half of the stations, which was quite amazing.

To have an objective view of current practice, one needs access to raw transmissions of many stations.

Normalized to 0 PPM

It was decided to virtually "correct" this omission by normalizing the graph to have all stations peak at 0 PPM = -9 dBFS. This is illustrated in **Fig. 2**, which shows what happens if the current ITU-R recommendation[1] would be observed by everyone, without changing other routines. Some stations show no digital sample peaks above 0 PPM (peaking at -9 dBFS), others peak higher, even up to +1 dBFS. About 37% of the measured channels have less than 2 dB difference between 0 PPM and maximum digital sample peak. The majority keeps more headroom above 0 PPM, although many do not seem to align 0 PPM to -9 dBFS.

Watching the LKFS levels in **Fig. 2** is an educational experience. Loudness levels still vary widely. From -28 LKFS (TRT International) up to -16 LKFS (Nederland 2, Nederland 3, RTL Television): a difference of 12 dB. A peak standard such as ITU-R BS.645-2[1] clearly does not regulate loudness. Loudness level differences can also be found between different measurements of the same station. Some of these are due to fragments including or excluding commercial breaks, although this collection brought about only 2 dB differences. Comparing several 6-min program fragments of BBC1, however, showed average loudness levels ranging from -23 LKFS to -16 LKFS. Level consistency currently can be pretty low when normalizing 0 PPM peaks.

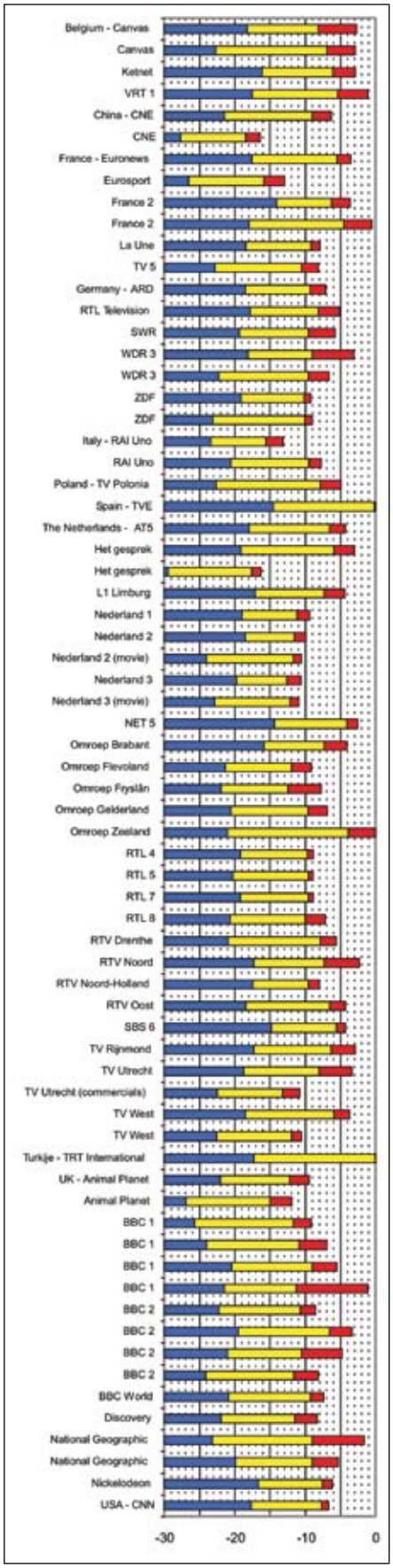

Figure 1. Measurements of 50 stations: LKFS loudness, PPM peak and digital peak.

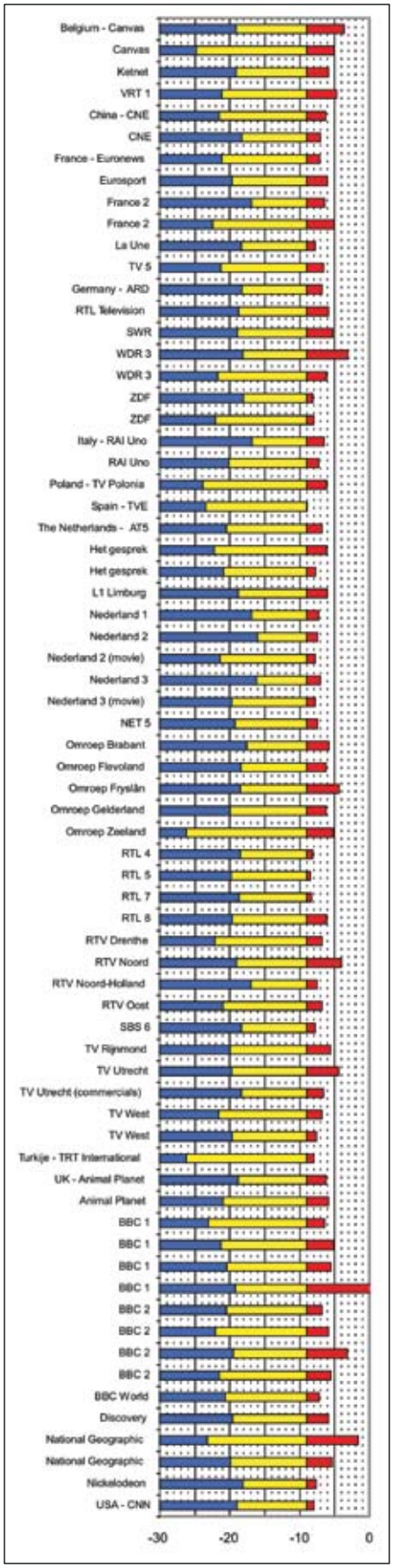

Figure 2. The same measurements, normalized to all PPM max levels equal -9 dBFS.

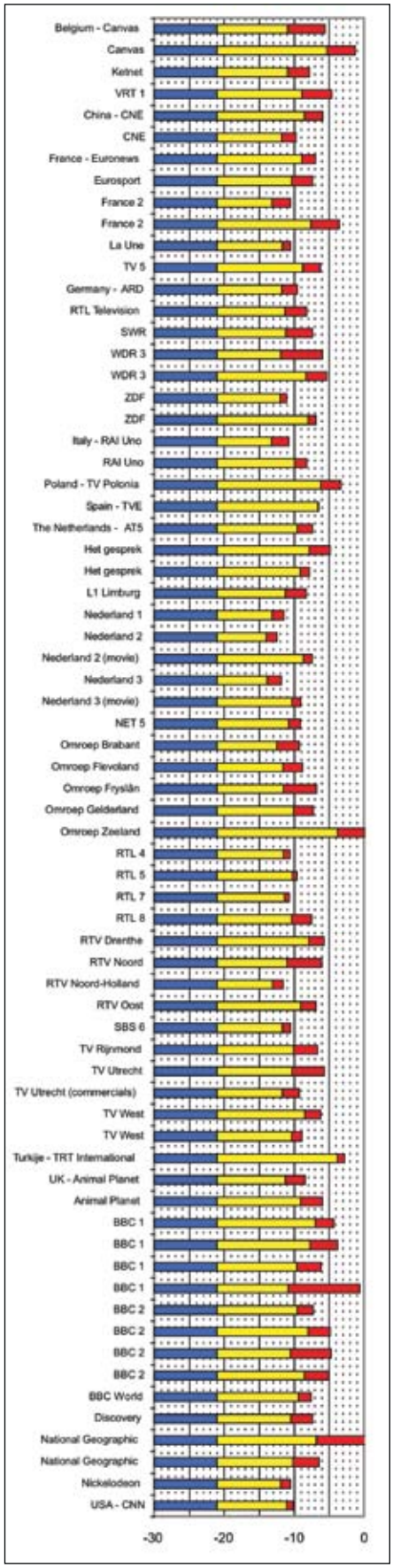

Figure 3. The same measurements, normalized to all LKFS levels equal -21 dBFS.

Normalized to LKFS

What matters to viewers is harmonized loudness levels—the LKFS value. This has to be included in any new recommendation. But what level should it be? This is a question about desired LPR. LPR is defined by the difference between perceived loudness level (in LKFS) and digital true peak levels; therefore, the first target is to determine the maximum peak level. A new recommendation should not interfere with stations featuring a reasonably wide LPR. When low-LPR stations line up LKFS level with wide LPR stations, no one has to change their routine. The low-LPR stations no longer peak to max. The opposite—to have wide LPR stations line up LKFS with low-LPR stations—leads to situations in which wide-LPR stations lose their character due to peak limiting. Now let us look at current use of LPR in the collection of stations, with sample peak measurements instead of true peak, as explained earlier.

- 19 to 20 dB: BBC1, Canvas, TRT International, Omroep Zeeland
- 17 to 18 dB: France2, TV Polonia
- 15 to 16 dB: BBC2, Animal Planet, National Geographic, VRT1, TV5, WDR3, TVE, RTV Noord, RTV Drenthe, RTV Oost, TV West, TV Rijnmond, TV Utrecht, Ketnet, Het Gesprek, Chinese News & Entertainment.
- 13 to 14 dB: Nederland 2 (movie), Net 5, BBC World, SWR, ZDF, Euronews, Eurosport, Discovery, RTL 8, RTL Television, Rai Uno, Omroep Fryslan, Omroep Gelderland, Omroep Brabant, L1 Limburg, AT5.
- 11 to 12 dB: Nederland 3 (movie), SBS6, ARD, RTL4, 5, 7, La Une, CNN, Nickelodeon, Omroep Flevoland.
- 9 to 10 dB: Nederland 1, 2, 3, RTV Noord-Holland.

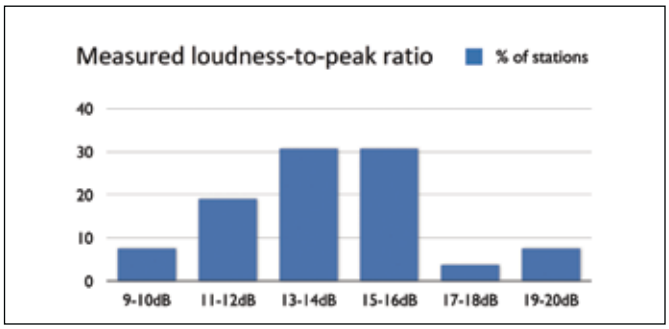

Figure 4. Categorization of measured loudness-to-peak ratio used by a sample of television broadcast stations in Europe.

Figure 4 gives a graphical representation of this categorization. Taking into account our premise that a new recommendation should not interfere with wide LPR stations, the LPR (sample peak) must be 16 dB. LPRs of 17 to 20 dB were caused only by occasional peaks. In general, such a wide LPR is also objectionable in a domestic environment.

The next question is what maximum digital sample peak levels do we find? If we analyze the maximum digital sample peak levels of the "15 to 16" dB LPR group in **Fig. 2** we get results ranging from -7 dBFS to -2 dBFS. Fifty-six percent had peaks between -5 dBFS and -6 dBFS. Higher peaks were quite rare—stations occasionally peaking at -2 dBFS most often peaked at -6 dBFS. It seems safe to select a maximum digital sample peak level of -5 dBFS; this is 4 dB above the 0 PPM alignment level. [In case of analog transmission feeds pre-emphasis limiters can be set to the same -5 dBFS.][24] Subtracting an LPR of 16 dB from -5 dBFS leads to a maximum loudness level of -21 LKFS. Incidentally, the -5 dBFS peak level corresponds with the PAL B/G recommendation.[18]

In **Fig. 3**, the loudness level of all fragments is normalized to -21 LKFS. When set as such, switches between programs and stations will show only minor loudness differences. As can be expected, peak levels in this graph vary widely because current loudness range of stations is divergent. Peak levels may also vary in the future, because of artistic choices by directors.

No audio level recommendation can be successful without control tools.

CONCLUSION AND PROPOSAL

We have investigated the use of loudness to peak range of 50 television stations by measuring their LKFS, PPM, and digital sample peak levels. A new audio level recommendation should include LKFS loudness levels and digital peak levels. Ideally this still complies with the current ITU-R/EBU recommendation for max PPM levels.[1] It should not limit the dynamics preferences of the majority of stations. A loudness-to-peak range between LKFS and the maximum digital sample peak of 16 dB was found to fit that requirement. Stations using this loudness-to-peak ratio and peaking at 0 dB PPM showed digital sample peaks up to approximately -5dBFS. The proposal therefore, is to set the maximum digital sample peak level to -5 dBFS and the maximum loudness level to -21 LKFS.

A recommendation such as this could be communicated to all content suppliers. Necessary measurement equipment is readily available. Anyone who for artistic reasons does not wish to use the full loudness-to-peak ratio bandwidth will automatically be aligned to -21 LKFS level and thus be equally loud as programs with a wider loudness-to-peak range. They are just peaking at lower levels. On the other hand directors who do wish to tell their story using loudness and peak contrasts will have proper freedom to do so, be it in a documentary or a commercial. Distribution companies can use the same recommendation; in fact some already comply by using LKFS in their automated leveling systems and leaving enough headroom for stations with high loudness-to-peak range demands.

Control

No audio level recommendation can be successful without control tools. The following suggestions are made for the various

stages in the broadcast chain. Further research into these is recommended:

(1) In digital media asset management systems, automatic program level attenuation down to the standardized LKFS level can be performed at the moment of intake. Implementation of this function has to be investigated. (2) The maximum level of loudness is -21 LKFS, but programs with too-low loudness levels are also objectionable for the viewer. Automatic amplification at the intake stage of (1) might be an option here. We recommend setting an LKFS threshold for amplification lower than -21 LKFS to cater for "film noir" like movies being softer on average. A level of -26 LKFS would be an educated guess, but research is needed to determine the right amplification threshold level. Alternatively, low audio levels could be gated from the measurement. This option is also in need of further research. (3) Any system should be able to deal with level accidents that often occur in live broadcasts or when by accident the cinema mix edition of a movie has been loaded in the media system. In cooperation with Orban Europe, we performed an experiment in which an audio processor was set to simultaneously have an instantaneous limiter for digital peaks above -5 dBFS and a 10 ms attack time limiter for peaks above -9 dBFS (mimicking a PPM). This appeared to impose the peak recommendation perfectly: PPMs never crossed 0 PPM, and digital peaks never exceeded -5 dBFS. It sounded good too!

POSTSCRIPT

After publication of this paper for IBC 2008, the EBU P/LOUD group was started and the authors participate on the committee. In 2010, the EBU recommendation R-128 will be set and as it seems the target level will be 2 dB lower at -23 LKFS, to allow for just a bit wider LPR. A gate has been added to address the "silent movie" problem. The maximum LPR as proposed in this paper is still seen as preferable for analogue distribution companies. This will be outlined in the distribution guidelines of EBU R-128.

REFERENCES

1. ITU-R Rec. BS.645-2, 1992, "Test Signals and Metering to be Used on International Sound-Programme Connections."
2. IEC Standard 60268-10, 1991, "Sound System Equipment—Peak Programme Level Meters."
3. ITU-R Rec. BS.1770, 2006, "Algorithms to Measure Audio Programme Loudness and True-Peak Level."
4. S. Klar and G. Spikofski, "On Leveling and Loudness Problems at Television and Radio Broadcast Studios," paper presented at the 112th AES Convention, Munich, Germany, May 2002.
5. J. Emmett, "Audio Level—In the New World of Digital Systems," *EBU Technical Review*, Jan. 2003.
6. B. C. J. More, B. R. Glasberg, and M.A. Stone, "Why are Commercials So Loud?—Perception and Modeling of the Loudness of Amplitude-Compressed Speech," *J. Audio Eng. Soc.*, (51) 12, Dec. 2003.
7. S. Klar and G. Spikofski, "Levelling and Loudness in Radio and Television Broadcasting," *EBU Technical Review*, Jan. 2004.
8. J. P. Moerman, "Loudness in TV-Sound," presented at the 116th AES Convention, Berlin, Germany, May 2004.
9. G. Spikofski, "Who Can Do Louder? Loudness Jumps in Broadcasting and How to Avoid Them?" 24th Tonmeistertagung International Convention, Leipzig, Germany, Nov. 2006.
10. D. De Leeuw, "Luidheidniveaus Reclameblokken; gemeten in de jaren 1999-2002, Adviesbureau Peutz," Presentation at Luidheidsymposium Televisiegeluid, May 2005.
11. Vereniging Constructief Audio. http://www.vcafilmsound.nl.
12. Luidheidsymposium Televisiegeluid, 't Spant Bussum, May 14, 2005.
13. W. Snel, "Luidheid in de praktijk—een onderzoek naar de praktische invoering van luidheidscontrole voor de Nederlandse televisie." USMT master thesis.
14. T. Lund, et al, "Loudness—A Change of Paradigms?" presented at the 124th AES Workship W7, Amsterdam, The Netherlands, May 2008.
15. ITU-R Rec. BS.1771, 2006, "Requirements for Loudness and True-Peak Indicating Meters."
16. Dolby Laboratories, Dolby Digital Professional Coding Guidelines. p88.
17. B. Katz, "Integrated Approach to Metering, Monitoring, and Leveling Practices, Part 1: Two-Channel Metering," *J. Audio Eng. Soc.*, 48 (12), Dec. 2000.
18. EBU Rec. R68-2000, "Alignment Level in Digital Audio Production Equipment and in Digital Audio Recorders.
19. ITU-R Rec. BS.707-5, 2005, "Transmission of Multisound in Terrestrial Television Systems PAL B, B1, D1, G, H and I, and SECAM D, K, K1 and L.
20. CENELEC EN 50083-5, 2003, Cable Networks for Television Signals, Sound Signals and Interactive Services—Part 5: Headend Equipment.
21. NOB, SLA-E1—Eisen aan informatie en materiaal (E1).
22. Jünger Audio C8000 Level Magic Audio Processors.
23. ITNM Systems ALC100 DVB Audio Level Control.
24. ITU-R BS.642-1, 1990, "Limiters for High-Quality Sound-Programme Signals: Section 10B—Frequency-Modulation Sound Broadcasting in Bands 8 (VHF) and 9 (UHF)."

LIST OF STATIONS MEASURED

Belgium – Canvas, Ketnet, VRT 1

China – Chinese News & Entertainment

France – Euronews, Eurosport, France 2, La Une, TV 5

Germany - ARD, RTL Television, SWR, WDR 3, ZDF

Italy – RAI Uno

Poland – TV Polonia

Spain – TVE

The Netherlands – AT5, Het gesprek, L1 Limburg, Nederland 1, Nederland 2, Nederland 3, NET 5, Omroep Brabant, Omroep Flevoland, Omroep Fryslan, Omroep Gelderland, Omroep Zeeland, RTL 4, RTL 5, RTL 7, RTL 8, RTV Drenthe, RTV Noord, RTV Noord-Holland, RTV Oost, SBS 6, TV Rijnmond, TV Utrecht, TV West

Turkije – TRT International

United Kingdom – Animal Planet, BBC 1, BBC 2, BBC World, Discovery, National Geographic Channel, Nickelodeon

United States – CNN

NOTES TO GRAPH 1, 2, AND 3

Measurements of all stations are presented. Blue level is maximum LKFS, yellow level is maximum PPM, and red level is maximum digital peak. Channels presented with 1 bar were consistent. The LKFS levels of all measured fragments have been averaged; the maximum PPM and maximum digital peak levels show the highest value. This is comparable to a long measurement, overlapping the content of the separate measurements. If a channel is present with more then 1 bar, the consistency of (some of the) fragments was low because differences in level were larger than 3 dB. Averaging would not be representative.

ACKNOWLEDGEMENTS

The authors would like to thank their colleagues of the Dutch Broadcast Loudness Committee for all our valuable discussions, Wouter Snel for his cooperation in this project, and the VCA for starting the project, back in 2004.

First published in the IBC 2008 Conference Proceedings, Amsterdam, The Netherlands, September 11-15, 2008. Copyright © International Broadcasting Convention. This paper was updated by the authors in February 2010.

Eelco Grimm has been technical editor and editor in chief of the leading Dutch professional audio magazine. He owns the recording and acoustical consulting company Fairytapes. He is co-owner of the high-end professional audio equipment manufacturer Grimm Audio. Grimm teaches and researches at Utrecht School of the Arts—Faculty Art, Media and Technology—School of Music Technology. He has developed measurement techniques and surround sound recording techniques and has produced acclaimed CDs, written a book on optimizing professional audio systems, and chairs the Dutch Broadcasting Loudness Committee. Grimm is member of the EBU P/LOUD committee.

Richard van Everdingen started his career as a computer engineer at Getronics. He then moved to cable operator Casema, where he specialized in head-end systems. Everdingen led the development of a patented measurement system for FM modulated broadcasting; a loudness based leveling system for dedicated rebroadcasting use and a leveling system for DVB distribution, directly operating in the MPEG domain. He currently works as a consultant for broadcast companies at NKM in the Netherlands. Everdingen is a member of the Dutch Broadcast Loudness Committee and leads the Distribution Subgroup within the EBU P/LOUD committee.

Michel Schöpping studied musicology with additional courses in choir-direction and public relations. He started his career as a film music composer but soon got involved in sound design and film mixing. Schöpping designed, edited, and mixed dozens of documentaries, art films, and features for television and cinema. He was producer for several CD recordings and directed two music documentaries. Currently, he works as a sound designer, dubbing mixer, composer, music supervisor, and consultant. Additionally, he teaches at the Netherlands Film and Television Academy.