DAB Norway

— implementation of loudness normalization

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The EBU has contributed considerably to making recommendations, guidelines and generally spreading the word about loudness. We can now see a loudness revolution all around Europe. And those broadcasters who have implemented it are telling us about their many happy listeners.

Thus far, loudness awareness has been almost exclusive to television. Could loudness normalization also be employed in radio? And if yes, what radio platforms could benefit from it? This article is about how we successfully implemented loudness normalization on DAB broadcasts in Norway ... with a few words about other radio platforms as well.

EBU R 128 Loudness in 60 seconds

Finally, we have a proper way of measuring audio levels the way we perceive them. The ITU gave us the basics and the EBU refined this to an important recommendation with four more important technical documents to cover all the details. If you are quite new to this stuff and "R 128" does not ring a bell, I strongly recommend you to read the excellent introductory article on this topic: "**On the way to Loudness nirvana**", by Florian Camerer, in EBU Technical Review, 2010 Q3 [1].

> ***" Loudness normalization is one of the most fundamental changes in the history of audio in broadcasting: the change of the levelling paradigm from peak normalization to loudness normalization. This change is vital because of a problem that has become a major source of irritation for television and radio audiences around the world: jumps in audio levels at the breaks within programmes, between programmes and between channels. Loudness normalization is the solution to counteract this problem. "***
>
> Florian Camerer, ORF

No matter what kind of content you are broadcasting, the measured loudness level tells you how "loud" your programme is. And here, "programme" can be anything from a commercial, a song or a feature movie up to 24 hours of output from your radio or TV station. By making the loudness level equal for all programmes and stations, we can deliver consistent audio levels to our listeners. The goal is to let our listeners forget about the remote control, at least the volume control part of it.

Based on the ITU-R BS.1770 specification on how to measure loudness and true peak levels, the EBU has specified three new parameters, called *Programme Loudness*, *Loudness Range* and *True Peak Level* in Recommendation R 128 [2].

Programme Loudness is a long-term integrated number that simply describes your programme's loudness. It is measured in dB and in two ways:

- LUFS is the ***loudness level*** with reference to digital ***full scale***. The EBU has defined –23 LUFS as the recommended target level.
- If you measure loudness with –23 LUFS as a reference, your loudness will be represented as LU (i.e.: 0 LU = –23 LUFS).

Loudness Range is a statistical description of your programme's variation in loudness, not unlike parameters such as *crest factor* or *dynamic range*, only much more reliable.

Finally, we need to keep track of our peak levels, but this time we want the ***True Peak Level***. VU-meters, (Q-)PPM meters or sample peak meters don't reflect the true peak levels, i.e. the peak levels that oversampling filters and bitrate reduction encoding etc. have to face. R 128 recommends keeping the True Peak Level below –1 dBTP when working with linear PCM.

For more details, I strongly recommend that you read EBU Tech. Doc. 3343: **Practical Guidelines for Production and Implementation in accordance with EBU R 128** [3].

"The loudness war"

Dynamic compression has been used by broadcasters and the music industry for decades. The purpose is to tailor the dynamics of the programme or the music to better suit the end user's listening environment. Dynamic compression has been used even on classical records since long before the advent of the CD. You just cannot have the same dynamic range in a typical living room as you may have in a concert hall. So initially, dynamic compression is often a necessity.

Abusive use of dynamic compression has lead to the so called **loudness war**. The loudness war or "loudness race" is a pejorative term for the apparent competition to digitally master and release recordings with increasing loudness [4].

The loudness war is said to have originated with the record companies back in the 1960s. Jukebox owners in cafés and bars had preset the playback volume to a certain fixed level. So, in order to stand out from the crowd, record companies such as Tamla Motown started to push the limits for how loud 7" vinyl records could be made. The advent of the CD changed the level restrictions dramatically. With digital, there is a clear limit to how loud the levels may be before clipping occurs. However, digital signal processing opens up new possibilities for maximizing the audio levels, like "brick wall limiters".

In the last decade, we have seen an increasing trend to make CDs sound louder, some of them actually so loud that the term "hyper compression" has been introduced. Although the sample values in hyper-compressed CDs are still valid, the only way to convert those CDs to analogue without distortion is to lower the level before analogue conversion.

Look at the two illustrations in *Fig. 1*. These are screenshots from Adobe Audition, showing waveforms of two songs ripped from CDs. On the left is Dire Straits' "Private Investigations" from the album "Love Over Gold" (1983). On the right is Maximo Park's "Graffiti" from the album "A Certain Trigger" (2005). As the waveforms suggest, the Dire Straits' song is quite dynamic while the song from Maximo Park sounds very "packed" and distorted.

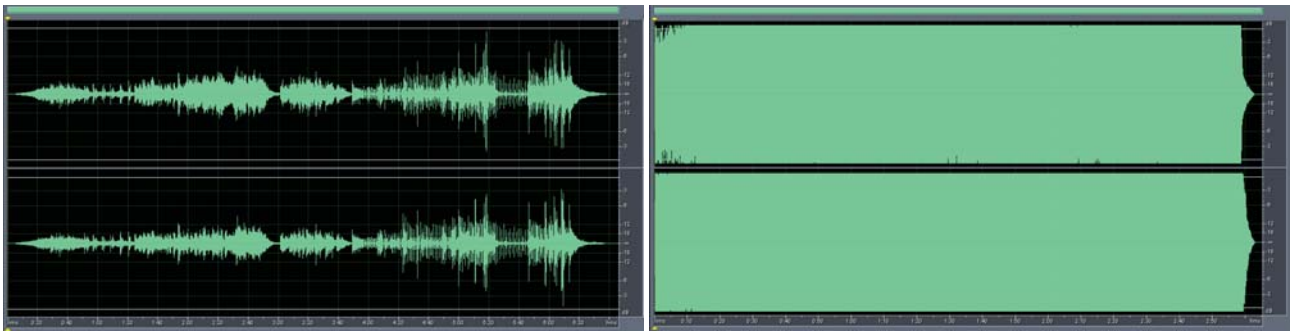

Figure 1
Waveform comparison between a Dire Straits track *(left)* **with a Maximo Park track** *(right)*

Loudness analysis of the two songs gives us the “truth”:

	Programme Loudness	Loudness Range	True Peak Level
Dire Straits	–24.4 LUFS	16.1 LU	–1.1 dB
Maximo Park	–5.5 LUFS	1.6 LU	+0.8 dB

The true peak levels differ by only 2 dB, but a difference of almost 19 LU in the programme loudness is a very large step in level for the Maximo Park track. If you played these two songs, one after the other, you most certainly would grab for the remote control to adjust your playback level. The loudness range of the Dire Straits song is actually too large for certain listening environments, for instance when walking with earbuds in a street with heavy traffic. To me, the Maximo Park song is just unbearably loud. It hurts the ears to play that song on a good Hi-Fi system.

Actually, unless you have the original Sony non-oversampling CD player from 1983, you cannot play hyper-compressed CDs without massive distortion. This occurs in the digital oversampling filters and/or D-to-A converters of most CD players. A good study, by Nielsen & Lund, with a practical example of hyper-compressed CDs can be found in [5]. This study also shows that peak levels of hyper-compressed audio may increase by up to 5.4 dB when the audio is coded using low bitrate reduction (in this case, MP3). Recent studies by Swedish Radio (still unpublished, to my knowledge) show increases in peak levels of up to 8 dB when coding hyper-compressed audio for DAB+. Hence, ripping CDs that are maximized to 0 dBFS and storing the content with lossy bitrate compression can result in massive clipping and distorted sound.

Even though hyper compression is still not used on classical CDs, a quick check of the Red Book layer of 20 SACDs from well-respected record companies shows clipping in about 50 % of the records.

Sadly, the loudness war is not exclusive to the music industry. Broadcasters have been fighting this war for years. In Norway, it started when NRK’s broadcasting monopoly was lifted. This happened in the early 1980s for radio and the early nineties for television. On analogue broadcasting, there are regulations and laws on how to behave. On the digital platforms, however, we still see little or no regulations from the regulatory bodies.

Concerning TV, the Norwegian public mostly complain about the audio levels in commercials and promos, and on level differences between programmes and channels. On FM radio it is different. Channels aimed at the younger public, mostly playing pop music, are very loud all the time. Even lighter channels, aimed at a more “mature public”, are also quite loud in general. This trend originates from FM and has also found its way into DAB and other digital radio platforms.

The use of multi-band transmission processors for maximizing the levels and still complying with regulations is widely used on FM. Some stations use the same transmission processors on FM and

Abbreviations

AAC	Advanced Audio Coding
DAB	Digital Audio Broadcasting (Eureka-147) http://www.worlddab.org/
DAB+	DAB using the AAC codec
DMB	Digital Multimedia Broadcasting http://www.worlddab.org/
DVB	Digital Video Broadcasting http://www.dvb.org/
DVB-C	DVB - Cable
DVB-S	DVB - Satellite
DVB-T	DVB - Terrestrial
FLAC	Free Lossless Audio Codec
FM	Frequency Modulation
ITU	International Telecommunication Union http://www.itu.int
ITU-R	ITU - Radiocommunication Sector http://www.itu.int/publications/sector.aspx?lang=en&sector=1
LU	Loudness Unit
LUFS	K-weighted Loudness Unit with reference to digital Full Scale
PCM	Pulse Code Modulation
PPM	Peak Programme Meter
S/PDIF	Sony/Philips Digital InterFace
SACD	Super Audio CD
SNR	Signal-to-Noise Ratio
VU	(Audio) Volume Units

DAB, some have separate processors and some channels are exclusive on DAB. The only nice thing to say about hyper compression with multi-band transmission processing in radio is that the output levels are very consistent and therefore easy to alter for loudness normalization.

FM and DAB in Norway

The transition from analogue to digital on TV went very smoothly and swiftly in Norway. We started with MPEG-4 DVB-T in September 2007 and two years later the last analogue transmitter was shut down. Sadly, we have not seen the same swift take-up on the radio platforms.

Due to Norway's difficult geographical topology, it is quite demanding to cover the country with terrestrial broadcasting. NRK's main channels on FM use about 100 main transmitters and some 900 gap fillers for >99% population coverage. The cost of parallel transmission on FM and DAB is very high, so shutting down FM is an important economical issue.

We started with test transmissions on DAB in 1994. Today, there are two DAB networks with national coverage in Norway, one single-frequency network and one network divided into seven regions. In total, there are 20+ radio channels (DAB / DAB+) and 20% of the radio listeners use DAB radios. Since 2007 we have had 80% population coverage on DAB. This will increase to 90% by 2013 and to 99.5% by 2015. A political decision has been made to switch off the FM broadcasts in 2017.

More information on DAB in Norway can be found here: **http://digitalradionorge.no/in-english**.

Since 2009, we have also had a DMB single frequency network with four transmitters covering the greater Oslo area. We call this "Mini-TV". More information on the DMB trials in Norway can be found here: **http://www.minitv.no/** (in Norwegian but with links to relevant news stories in English, e.g. from Broadband TV News).

There are some very fundamental differences between distribution of FM and DAB, or rather analogue and digital radio. On FM, there are some benefits of using highly-compressed audio, due to low SNRs and massive multipath distortion on the outer edges of the coverage area, particularly in the case of mobile reception. This benefit does not exist in digital radio, where the SNR is a massive 90+ dB right up to the brink of reception. Over-modulation on FM distorts the sound and can potentially influence the neighbouring channels; on digital platforms, over-modulation only affects the actual channel itself.

There are three main content providers on national FM in Norway. NRK is the public broadcaster, while P4 Radio Hele Norge and SBS are commercial broadcasters. For some years now, we have had regular informal contacts to discuss and harmonize our FM levels. This cooperation has been very fruitful and, as the same three companies have also moved to DAB, we have continued to meet. In February this year, we managed to agree on loudness normalization for the national DAB platform. More about that later!

FM measurements

To confirm the ongoing loudness war on FM, I hooked up a directional antenna to an Audemat Aztec FM navigator, connected to a laptop computer running FM Explorer software. I made sure that the RF level was high enough for reliable measurements. Weak signals, multipath distortion etc. give unreliable results. Since all hyper-compressed FM stations play pop music, I decided to measure FM-multiplex deviation during one song from each station. The Audemat Aztec samples the total FM channel multiplex with 500 kHz sampling frequency. Three times a second, the maximum peak value is stored and their accumulated statistical distribution is shown in the software window. The measurements have (linear) frequency deviation on the X-axis, with 75 kHz located in the middle of the graph (indicated by a blue dotted vertical line).

Two examples of these measurements are shown in *Fig. 2*. The one on the left is hardly using any compression at all, while the one on the right clearly belongs in the "hyper-compression" category. The one on the left stays below 75 kHz deviation for 97% of the time, has average deviation of 31.3 kHz and a maximum deviation of 104 kHz. The example on the right stays below 75 kHz deviation only 2% of the time, has average deviation of 76.8 kHz and maximum deviation of 80 kHz.

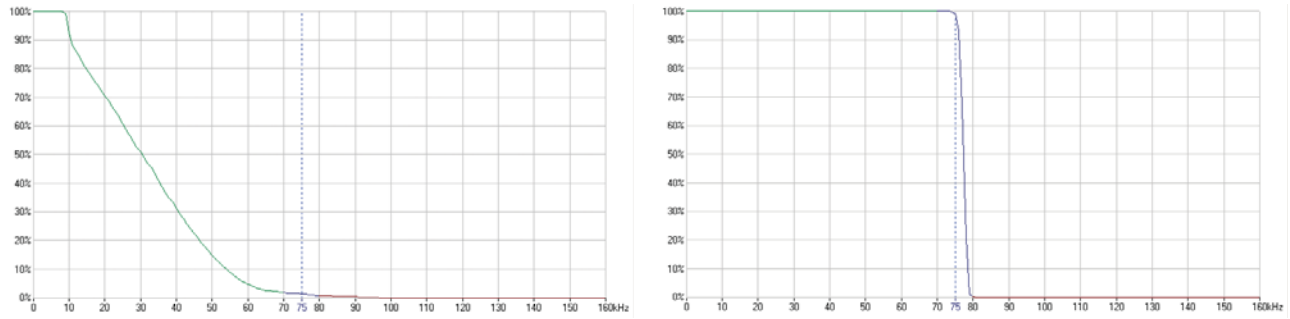

Figure 2
Two examples of FM deviation measurements

As you may already have guessed from the image on the right of *Fig. 2*, we do not employ the ITU's BS-412 MPX power limitation in Norway.

DAB measurements

It is quite easy to measure loudness reliably on DAB. You need proper RF levels, but do not have to worry about multipath distortion or other problems associated with analogue measurements. The only tricky part is the DAB tuner. It must have a digital output with levels you can trust. We have found that older "DAB-only" receivers seem to convert MPEG-1 Layer 2 audio to linear PCM and feed that out from their S/PDIF digital output, without any scaling of the audio levels. But we also found that newer DAB/DAB+ receivers have lower audio levels on their digital outputs than the older "DAB-only" receivers. For this reason, I chose to exclude DAB+ from my comparative measurements.

Stand-alone hardware meters are readily available for loudness measurements that connect to a DAB receiver's S/PDIF output. Since I was making a demo, I chose a software solution. Using a simple soundcard, I converted the S/PDIF output from the DAB tuner to USB for my computer.

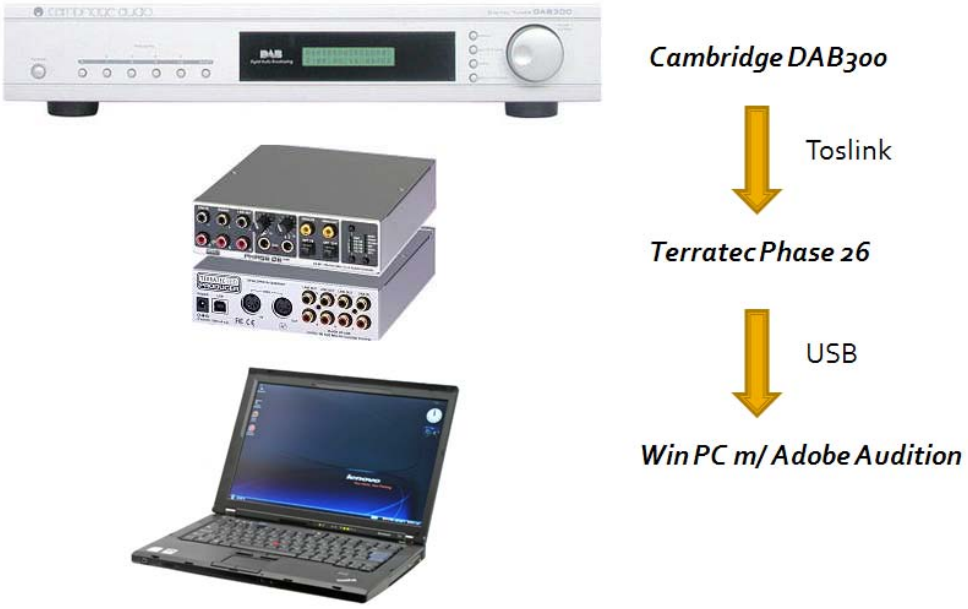

Figure 3
DAB recording setup

I recorded 15 minutes from each station, and then analyzed their loudness parameters using Grimm Audio's LevelOne software. The software was set in "EBU-mode", where 0 LU = –23 LUFS. A screenshot from Adobe Audition showing all stations is shown in *Fig. 4*, along with a screenshot of their analysis in LevelOne.

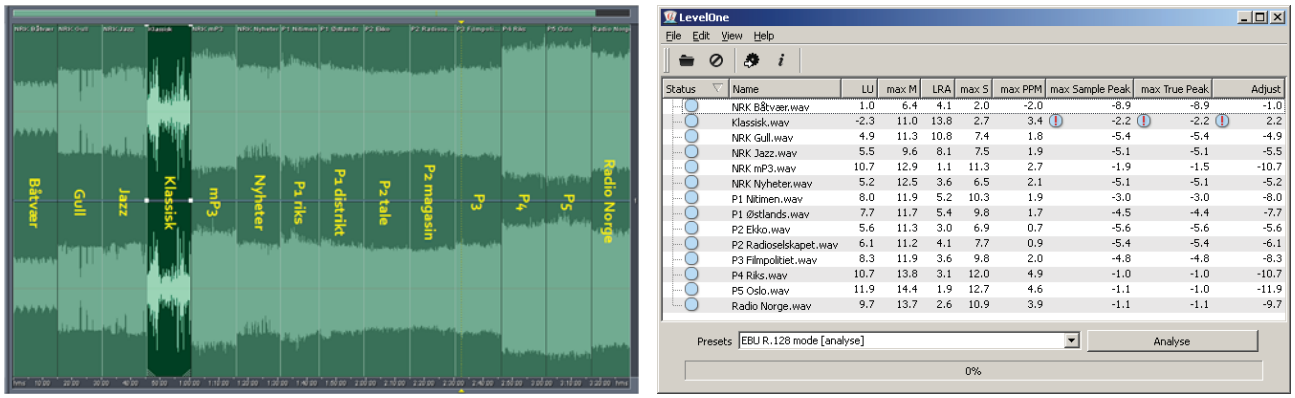

Figure 4
(Left) **Screenshot showing all DAB channels in Adobe Audition and** *(right)* **a screenshot of loudness measurements in LevelOne software**

The sample peak representation in Adobe Audition shows large variations in audio levels. The classical station is highlighted; it is no surprise that this station has the largest variation in dynamics. The loudness analysis gives us the facts. The difference in loudness between the loudest and the quietest station is 14 LU, while loudness range (LRA) varies from 14 LU to a miniscule 1.1 LU. The true peak levels for most stations where pretty high. The software issues a warning for the classical station (top row); it cannot be normalized to the EBU target of –23 LUFS without using peak limiting.

To illustrate the difference in levels a listener would experience when switching between stations, I made a "zapper-test". I took a 5-second clip from each station, starting 60 seconds into each recording. These clips where assembled into one audio file. I then normalized all 15-minute recordings, and copied out the same 5 seconds from each station, and made a new audio file. The two "before" and "after" loudness normalization files were adjusted again for equal loudness, in order to make a realistic demo. The result *(Fig. 5)* was very convincing. Loudness normalization really makes a difference. Even though the loudness range is very different, switching between loudness-normalized stations does not encourage the listener to change the volume setting. Mission accomplished!

You can listen to the result by following this link on the EBU's website:

http://tech.ebu.ch/news/norways-dab-network-embraces-loudness-no-13feb12.

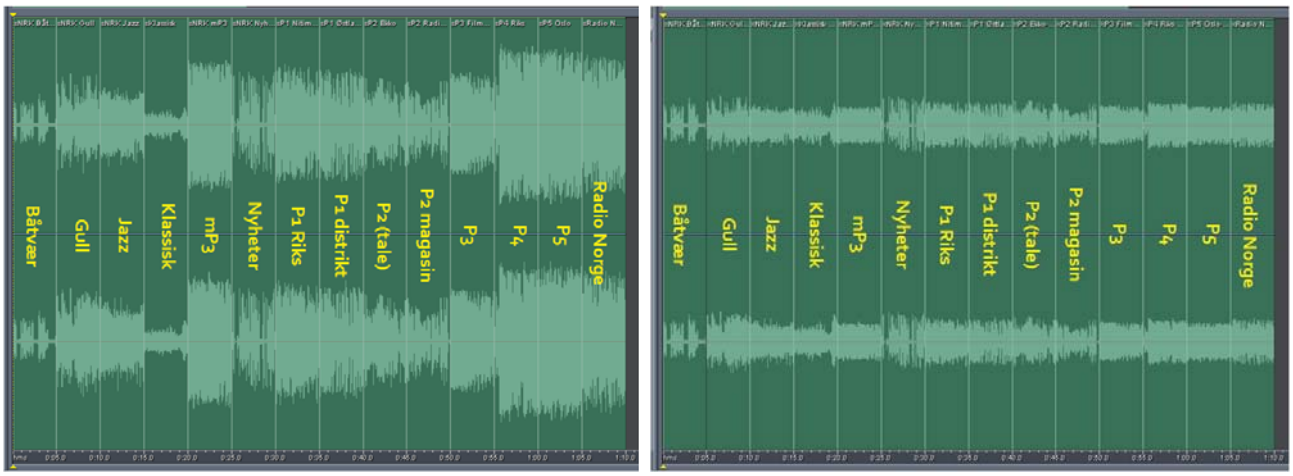

Figure 5
Adobe Audition screenshots: *(left)* **before normalization and** *(right)* **after normalization to –23 LUFS**

The agreement

FM used to be the only path for high-quality radio distribution. At least in Norway, the purpose of switch-over from FM to DAB has not been conveyed to the public successfully. What we have said since 1995 is that FM is going to be replaced by DAB. But this is not at all the whole picture. What we should say is that analogue distribution is going to be replaced by digital distribution. In Norway, you will already find radio on digital carriers such as DVB-T, DVB-S, DVB-C, the Internet etc. DAB is only replacing FM for mobile reception.

Since there are no regulations for audio levels on the digital radio platforms, it may seem difficult to agree on a common target level for loudness. I know that other countries are determined to make their DAB sound equally as loud as their FM transmissions. In my opinion, FM is quite inferior to DAB in audio quality and should not be used as a reference for audio quality.

The Norwegian agreement on loudness normalizing of the DAB platform is basically only an agreement on a common output level. The loudness range is still a result of the individual station's audio profile. And the true peak levels follow the loudness levels closely, as described above. In the long term, I hope to see a gradual back-down in hyper compression. But this is not really necessary to keep the listeners happy, level-wise. If a station decides to continue with hyper compression, it is their choice. In the end, the listeners will judge that decision.

Why –15 LUFS?

It took us less than two minutes to decide on loudness normalization for the DAB platform. But we found the target level of –23 LUFS as defined by the EBU in R 128 to be too low, at least for now. The main issue is the combined FM/DAB receivers and the level change when switching between platforms. As DAB today is the only realistic digital replacement for FM in mobile reception, we must

Figure 6
Agreeing on loudness levels on DAB in Norway, at the historic meeting held at P4's premises at Lillehammer Wednesday 8th, February 2012.
From the left: **Olav Fostås (P4), Dag Gulbrandsen (NRK), Kristoffer Løkke-Sørensen (P4), John-Arne Sviggum (P4), Henning Lie (SBS), Hans Petter Danielsen (P4), Petter Hox (NRK) and Bjørn Aarseth (NRK).**

keep the DAB listeners in cars happy. With Norway's difficult topology, we have a lot of road tunnels. And most road tunnels have FM coverage, but not many have DAB yet. So when you drive into a tunnel, listening to DAB, you're receiver will switch to FM. A level jump of 8-10 dB when switching from DAB to FM could be a traffic hazard!

We also decided to keep NRK's classical station outside the loudness regime. People already expect this channel to be lower in perceived loudness level when switching to it. And we do not want to interfere with their chosen large loudness range and high true-peak levels.

On the other hand, since the agreement on –15 LUFS as a preliminary target level actually translates to a level reduction on most stations, it is very easy to perform. Clipping is not an issue anymore.

Following up the agreement

We know that loudness normalization is the only way to keep our listeners happy. We have agreed to monitor ourselves and each other, and to convey our measurements to the others. But what happens if someone decides to increase their level? And what happens if there is a "new kid on the block" who decides to be louder than the rest. Well, there are no DAB-level policemen, no local or global regulators, and so we only have to trust each other. If someone insists on increasing their level, we have to rely on our listeners to complain. In the future, we would like to see some governing regulations on audio levels, whatever the platform.

EBU Tech 3344 [6] covers in detail how to measure and adjust loudness on all radio and TV platforms used in Europe.

The next step: R 128 in production

It did not take much effort to comply with the nationally-agreed loudness level. It just needed a figure for how many LUs each station should back down. And then we each had to make the adjustment. We could easily do this because all the competing stations use heavy compression and are quite loud in the first place. But we also know that their sound quality is very dependent on consistent audio levels in production, in order to make their station compressors operate as well as possible. Today, most radio channels are operated by people with lower skills in how to properly place audio levels. So the next natural step for us is to introduce R 128 also in production.

For NRK, R 128 in production will off course include both radio and TV. Most of our productions are file-based, so we will use loudness meters in both hardware and software. We expect to make the switch to loudness normalization on all our production platforms during 2013. Starting this year, all music files for radio production are being exported from our FLAC-based archive to loudness normalized (–23 LUFS) linear 24-bit, 48 kHz PCM.

Bjørn Aarseth was born and raised in the little town of Sandefjord on Norway's south-east coast. He studied electronics engineering at Gjøvik and Oslo technical colleges then, in 1981, joined the Norwegian Broadcasting Corporation (NRK). He spent the first two years at NRK as an audio maintenance engineer, before moving to the audio laboratory as an audio R&D engineer. Here, he tested and evaluated audio equipment, and designed analogue and digital audio electronics. Later he moved to system design, including the two DAB teaser channels "Alltid Klassisk" (non-stop classic) (1995) and "Alltid Nyheter" (24/7 news) (1997).

Mr Aarseth has given numerous internal training courses at NRK, particularly on the subject of digital audio. In recent years, he has been working mostly as an internal consultant on audio technology. "Anything audio" is his motto.

Bjørn Aarseth actively works with projects in the EBU, such as the B/DABA, D/MAE and P/LOUD groups. He is also a part-time lecturer in audio engineering at NISS (Nordic Institute of Stage and Studio).

Conclusions

With some precautions, it is quite easy to measure and loudness-normalize the digital radio platforms. “Loud” stations have very consistent levels with controlled peaks, and are the easiest to normalize, just by reducing their output levels after the final transmission processor. With consistent audio levels, zapping between the stations on DAB is a breeze. So far, we have had only positive feedback from the public and the industry.

Consistent levels on DAB also translated to a better level-matching between DAB and other platforms in multi-platform receivers. For the receiver manufacturers, this means a fixed level difference between DAB and FM, a definition which they have been wanting for years.

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The paper and audio examples can be downloaded from here:
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http://www.tcelectronic.com/media/Programmed_for_Distortion.zip

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