Normalization of Broadcast Audio

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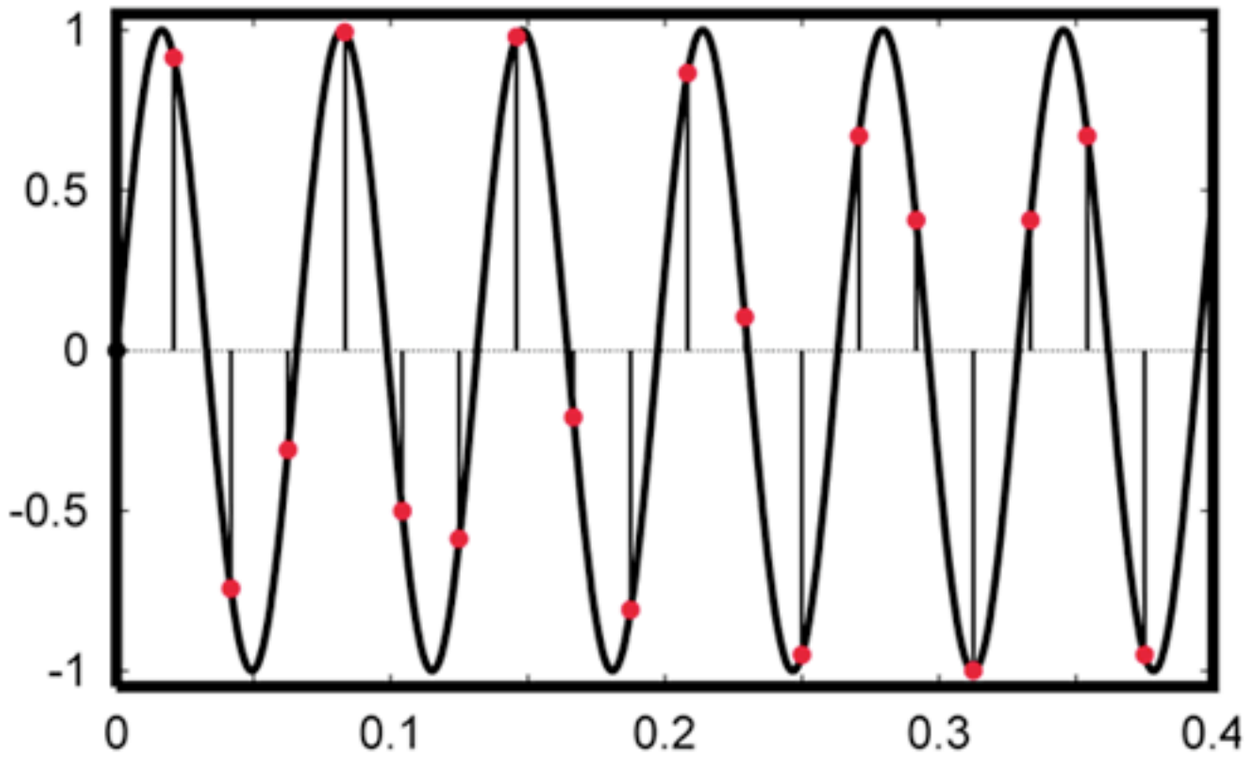
Peak Level

Even in a linear audio system, analog and digital level is not the same.

Analog Level:
Black Line

Digital Level:
Red Dots

1



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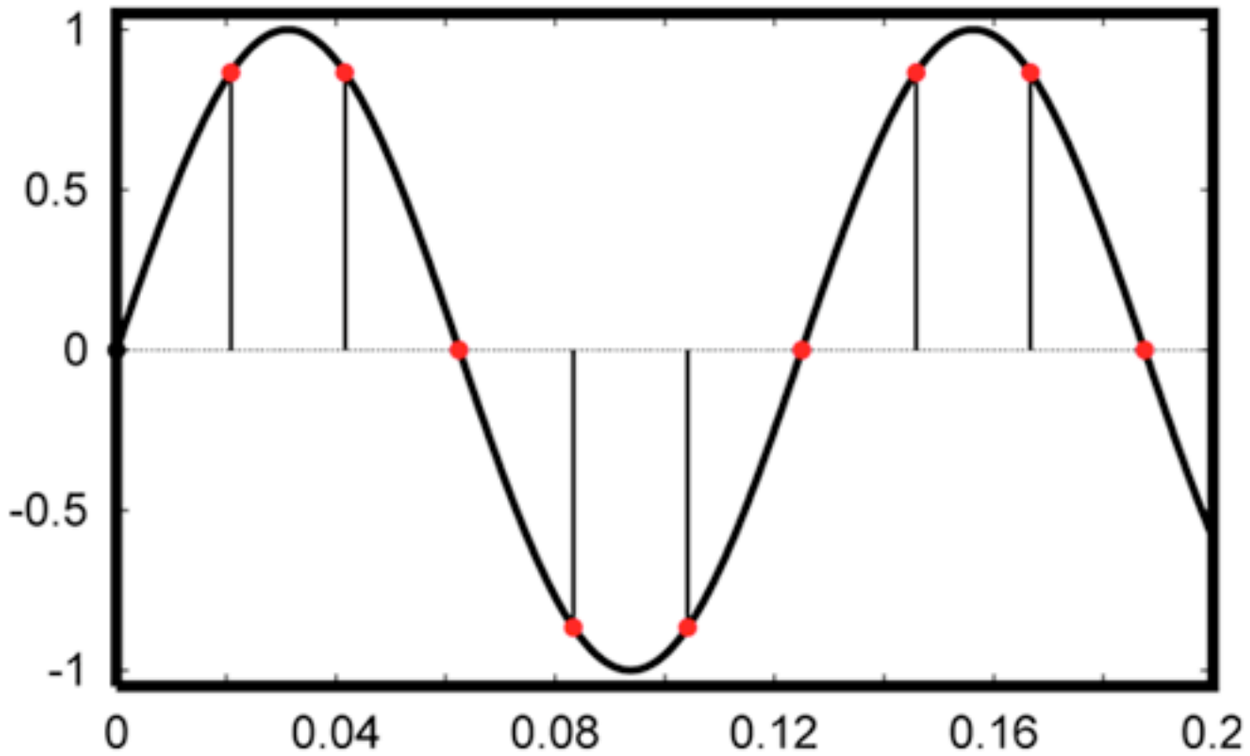


Audio Level

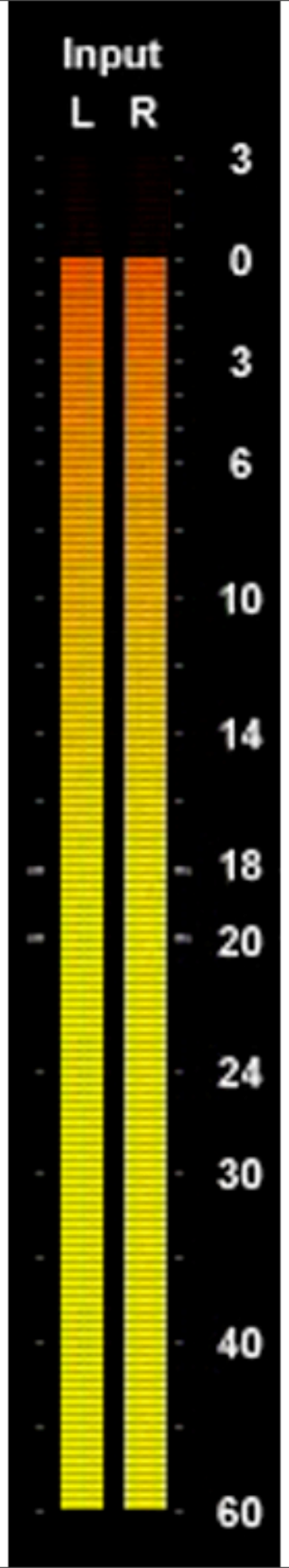
Critical Areas

Headroom is needed several places in the signal-path:

- DA Converters
- Filters, analog and digital
- Sample rate converters
- Data reduction codecs (e.g. MP3)

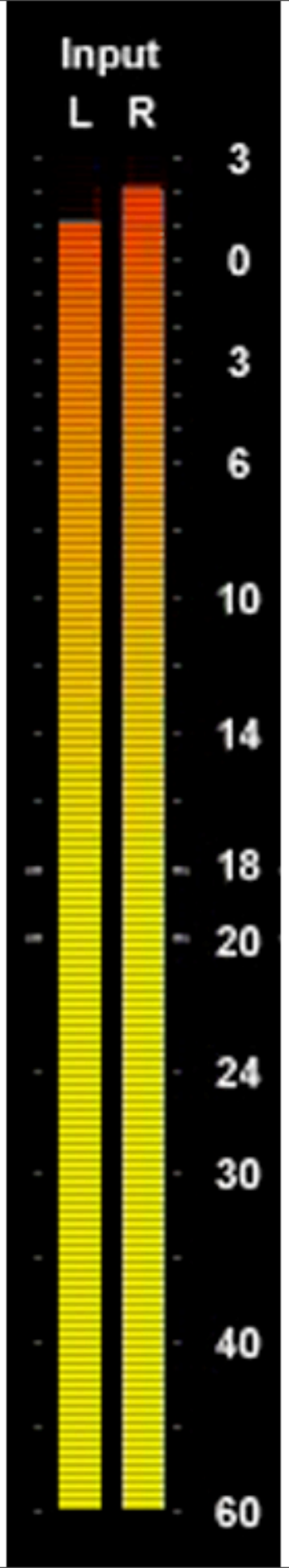
0 dBFS+ level is hit more and more frequently on new pop/rock releases.

True-peak



Sample
Meter

True-peak
Meter



maximum under-read (in dB) = $20.\log(\cos(\pi.f_{norm}/n))$

This equation was used to construct the following Table, which probably covers the range of interest:

Over-sampling ratio	**Under-read (dB) maximum $f_{norm} = 0.45$**	**Under-read (dB) maximum $f_{norm} = 0.5$**
4	0.554	0.688
8	0.136	0.169
10	0.087	0.108
12	0.060	0.075
14	0.044	0.055
16	0.034	0.042
32	0.008	0.010

CD True-peak Level

Original CD level

Bit cloned
No gain change
No sample rate conversion

Note: Meter must be digital & synchronous in order to display true-peak level correctly

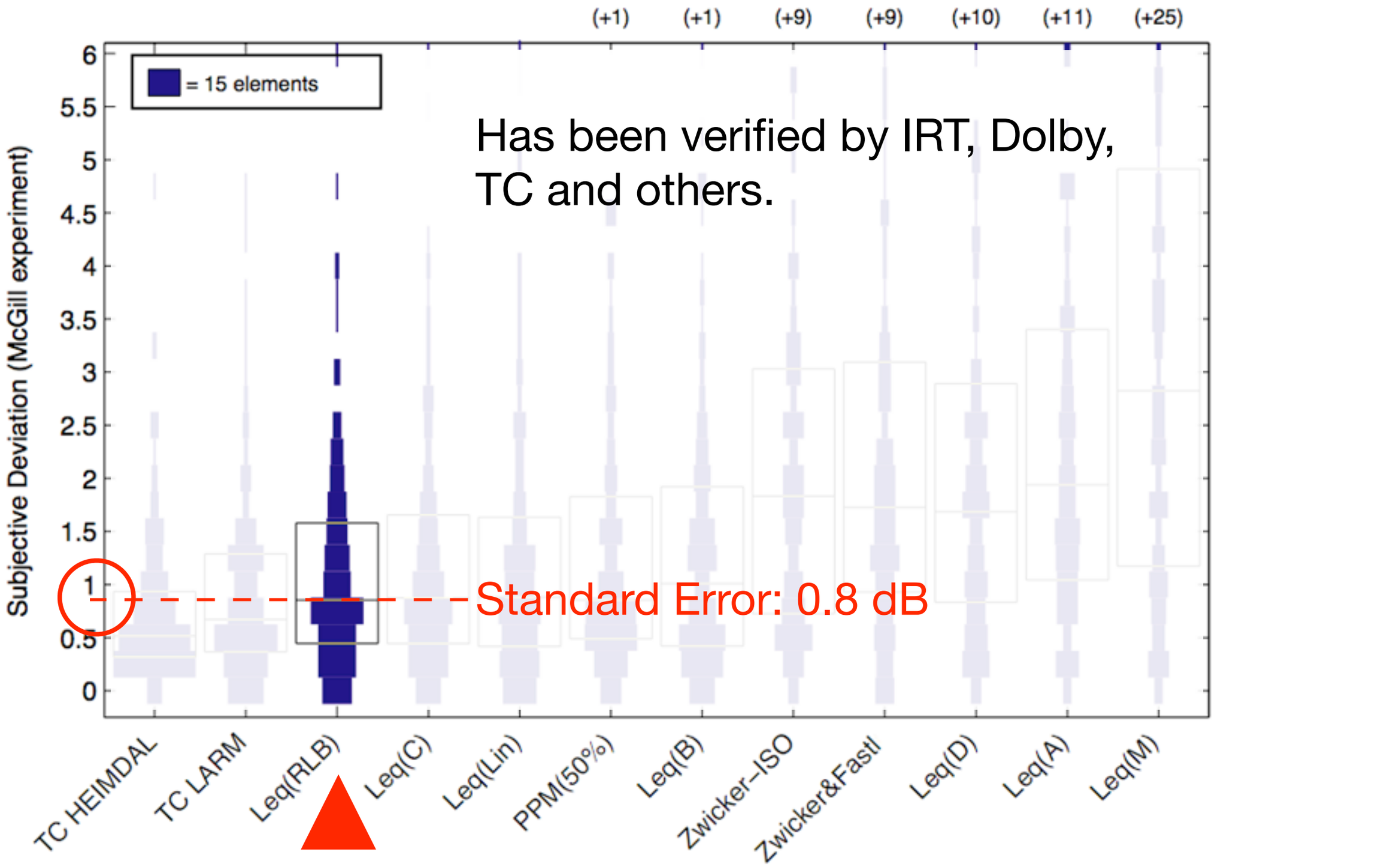
ITU-R BS.1770

A standardized way of measuring

- *loudness* and
- *true-peak level*

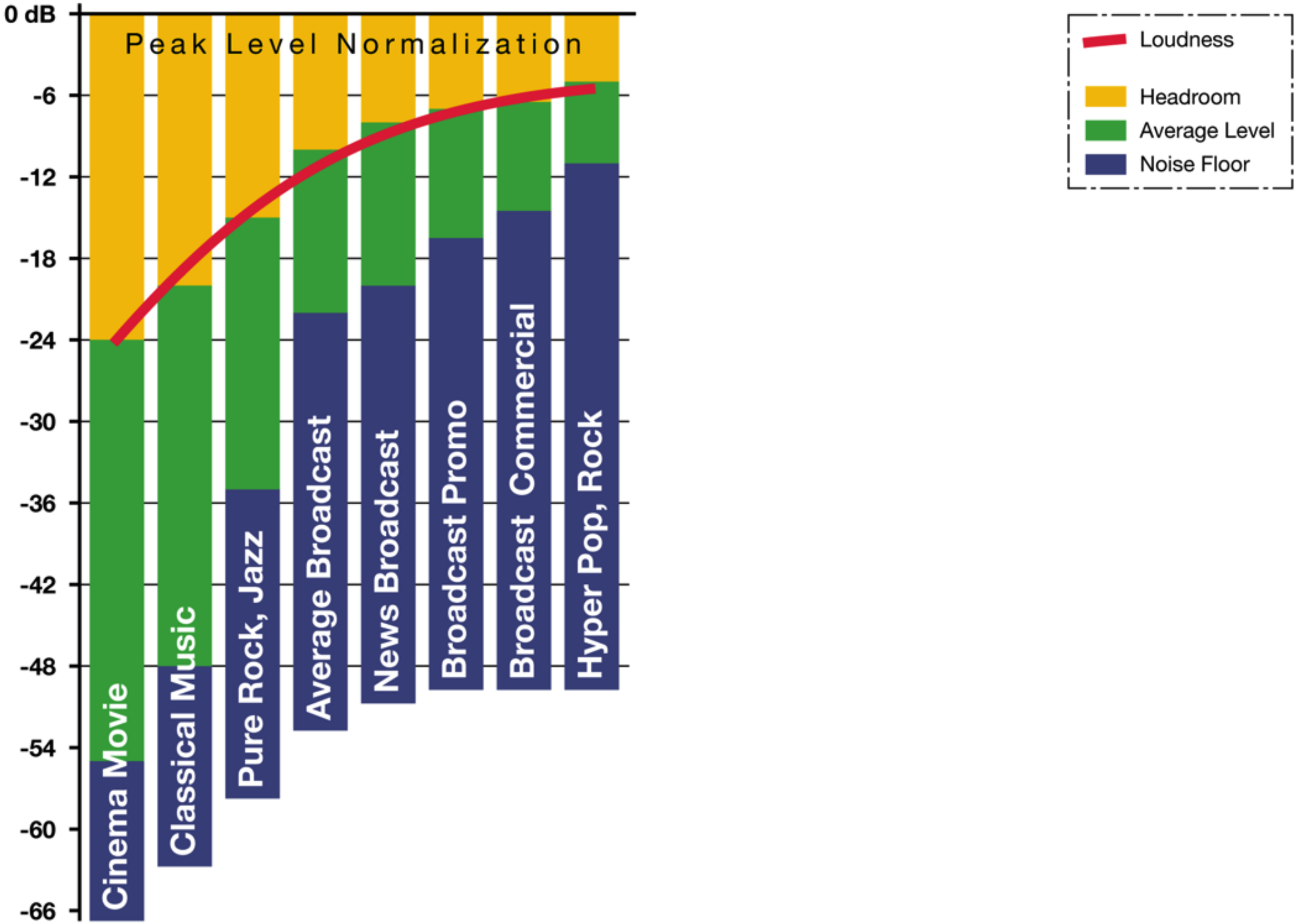
for mono, stereo and 5.1 content

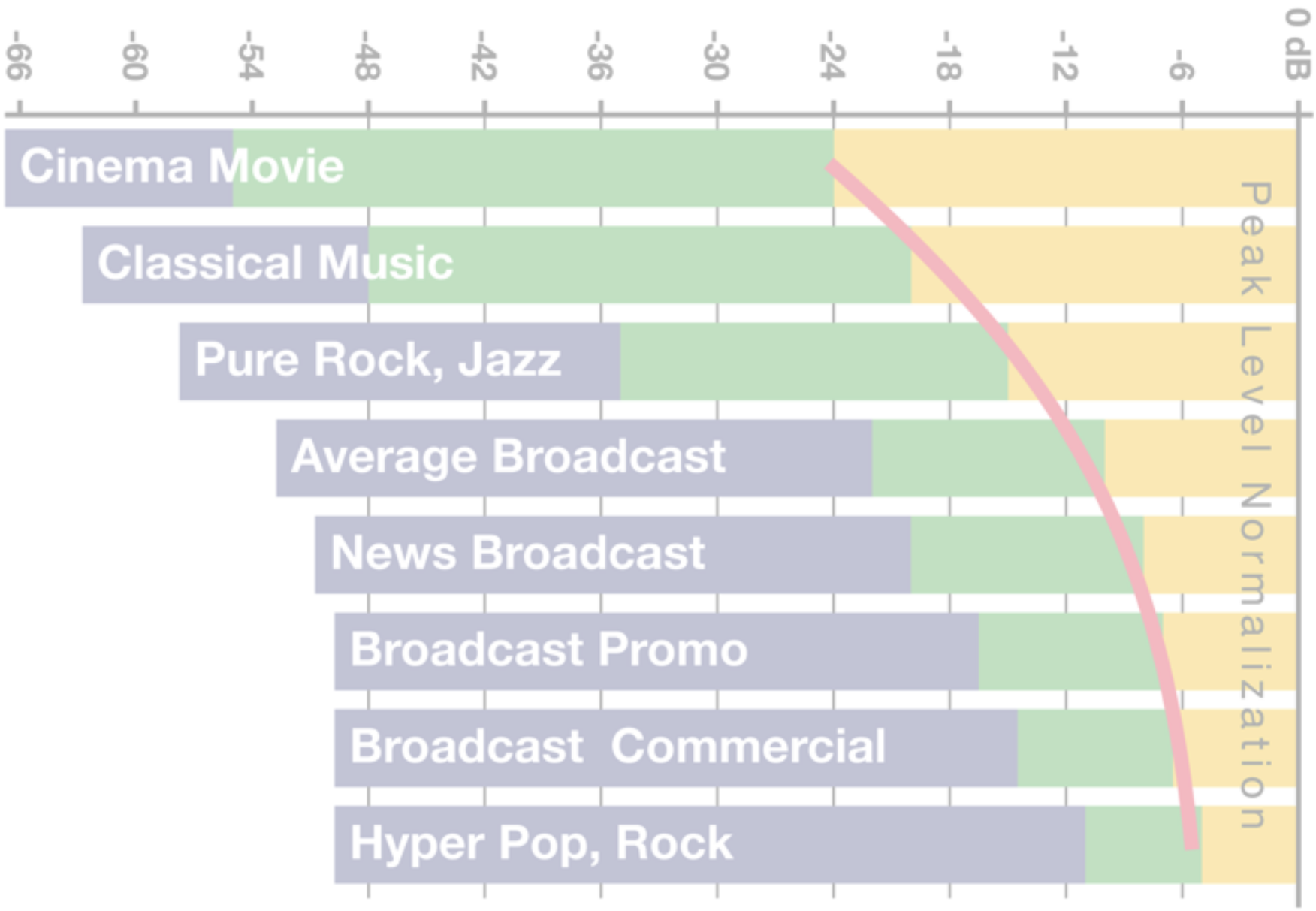
BS.1770 Loudness

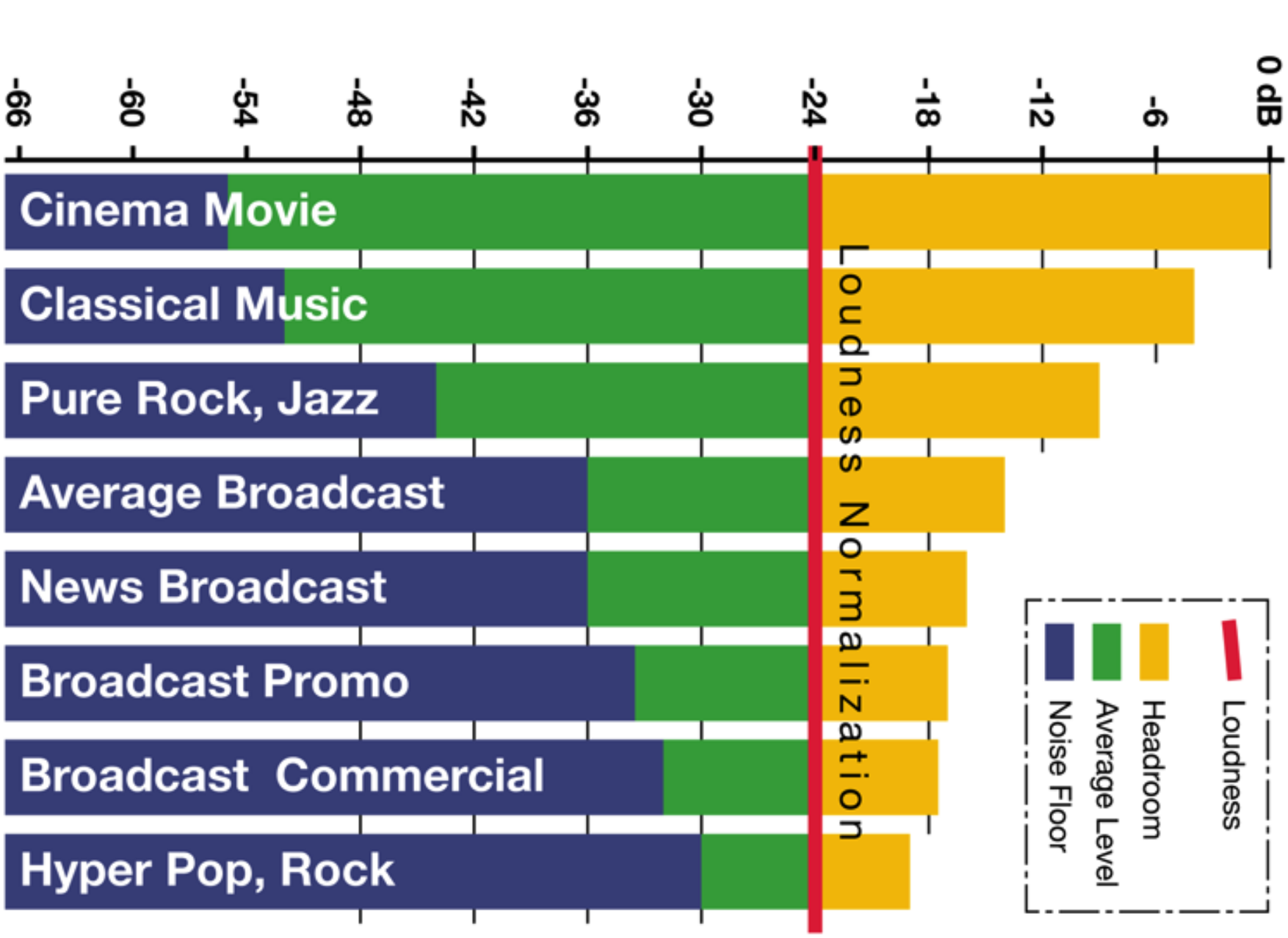


Has been verified by IRT, Dolby, TC and others.

Standard Error: 0.8 dB


Peak Level Normalization
0 dB
-6
-12
-18
-24
-30
-36
-42
-48
-54
-60
-66
Cinema Movie
Classical Music
Pure Rock, Jazz
Average Broadcast
News Broadcast
Broadcast Promo
Broadcast Commercial
Hyper Pop, Rock
Loudness
Headroom
Average Level
Noise Floor


-66
-60
-54
-48
-42
-36
-30
-24
-18
-12
-6
0 dB
Cinema Movie
Classical Music
Pure Rock, Jazz
Average Broadcast
News Broadcast
Broadcast Promo
Broadcast Commercial
Hyper Pop, Rock
Peak Level Normalization


-66
-60
-54
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News Broadcast
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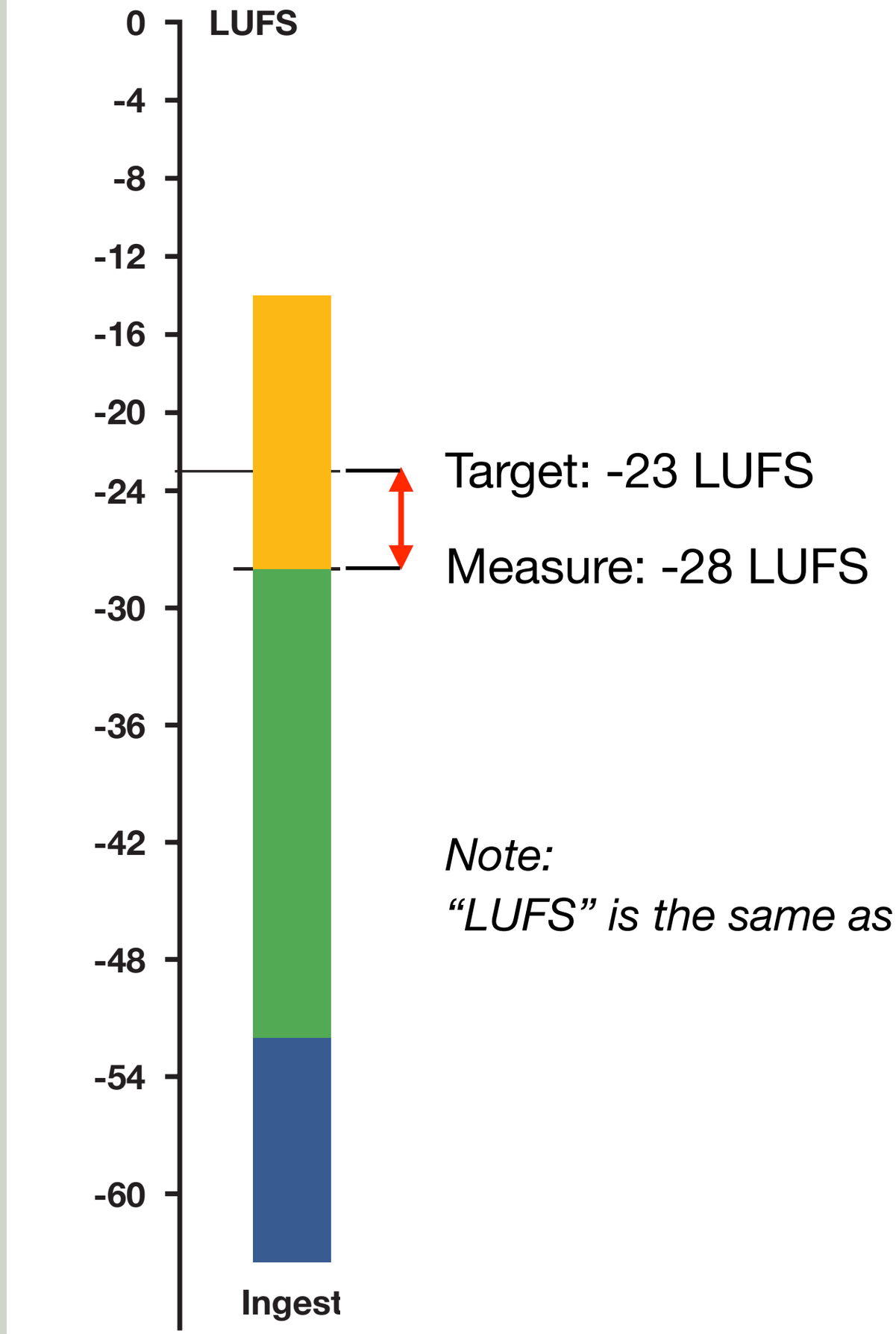
Broadcast Commercial
Hyper Pop, Rock
Loudness Normalization
Loudness
Headroom
Average Level
Noise Floor

Program Loudness

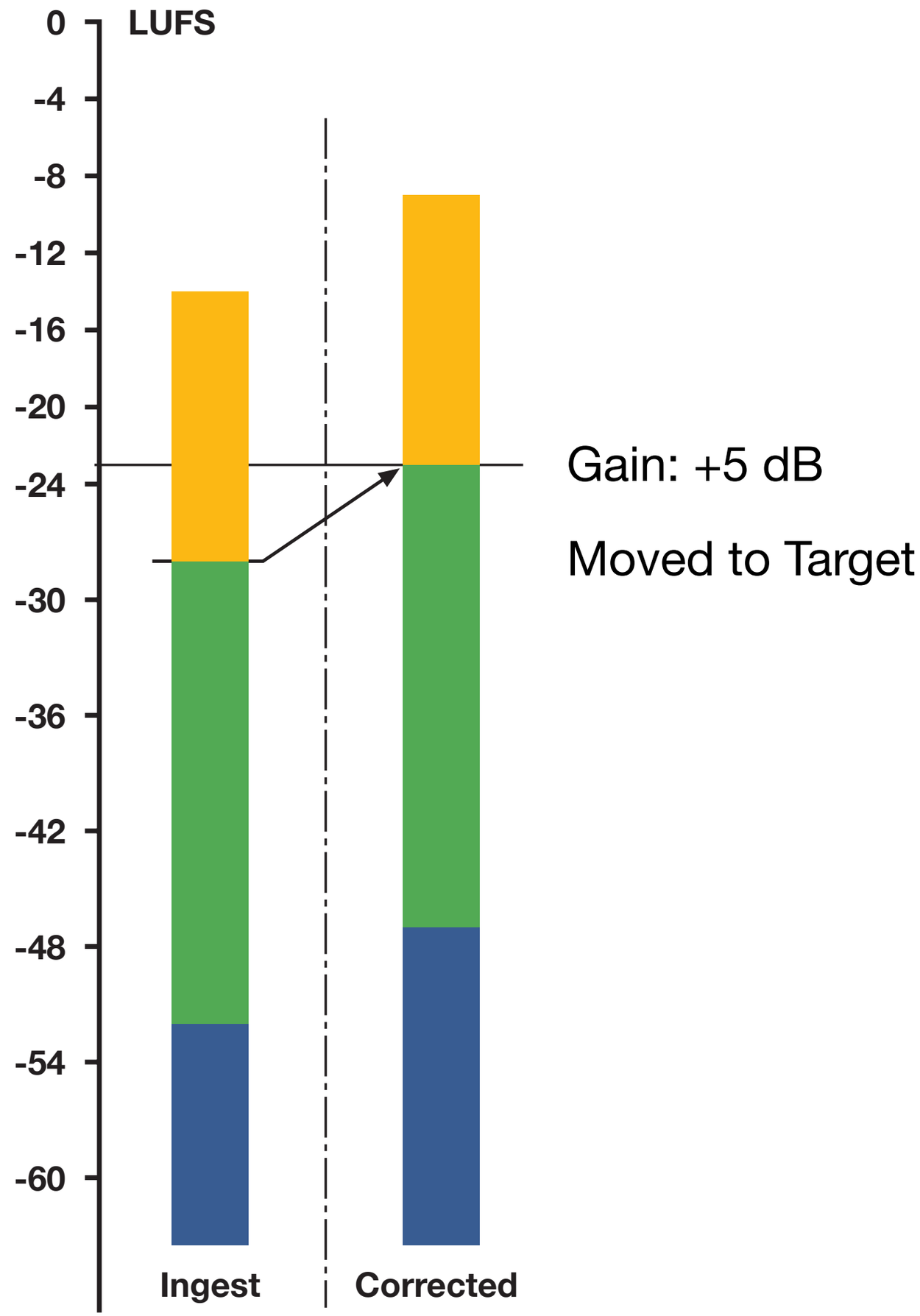
Use to normalize programs and commercials



Note:
“LUFS” is the same as “LkFS”

Program Loudness

Use to normalize programs and commercials

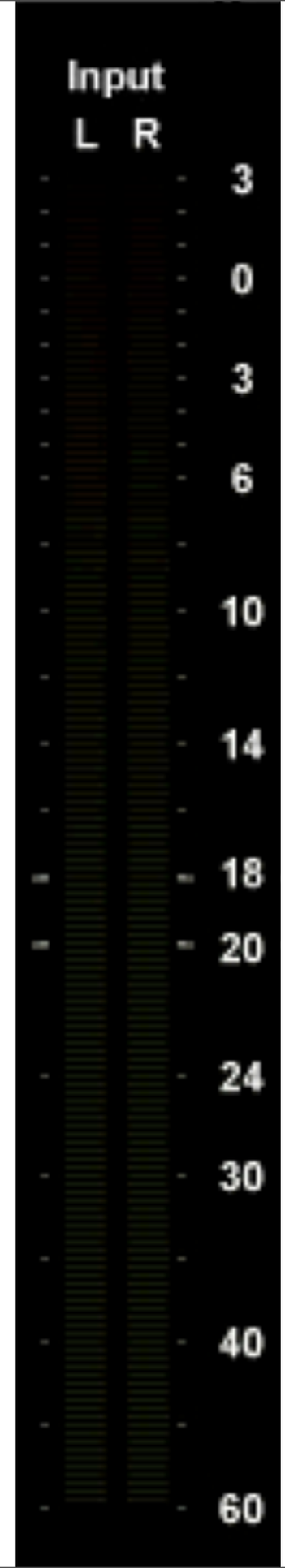


R128 Normalization

Observe peak level on these four tracks

Normalization based on R128 program loudness for the entire track

No processing



Agenda

Tolerance

Loudness Jump Tolerance predicts when a listener reaches for the remote control

Normalization

Optimized and transparent criteria for program normalization (= static gain offset for each program)

A/85 & R128

A comparison between new loudness based guidelines from USA, Japan and Europe

Loudness Jumps

How much can be tolerated between programs?

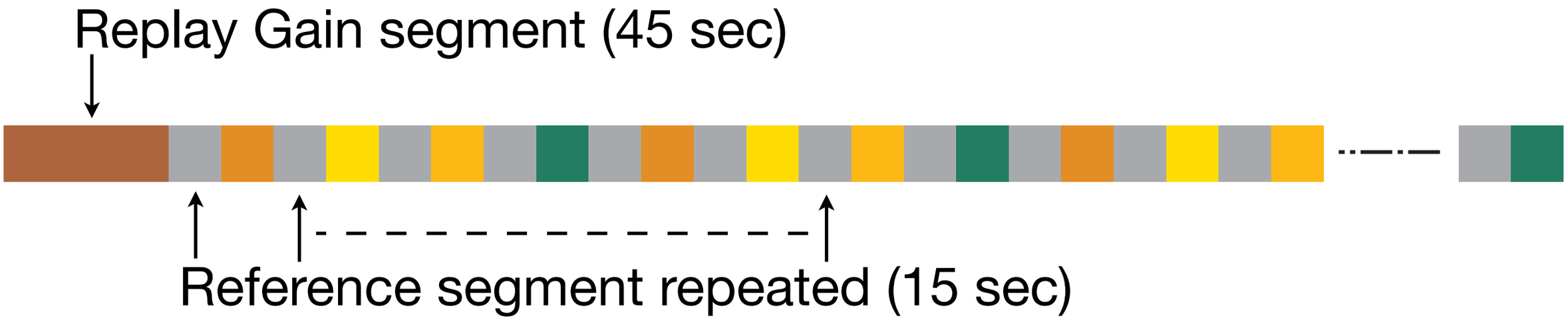
2003 “Comfort Zone” paper by Dolby

- Blind to anything but speech
- Study not based on BS.1770 when measuring segments

AES 2009 paper: New study based on BS.1770

- Commercials, drama, news, pop music, movie
- Measures all sources

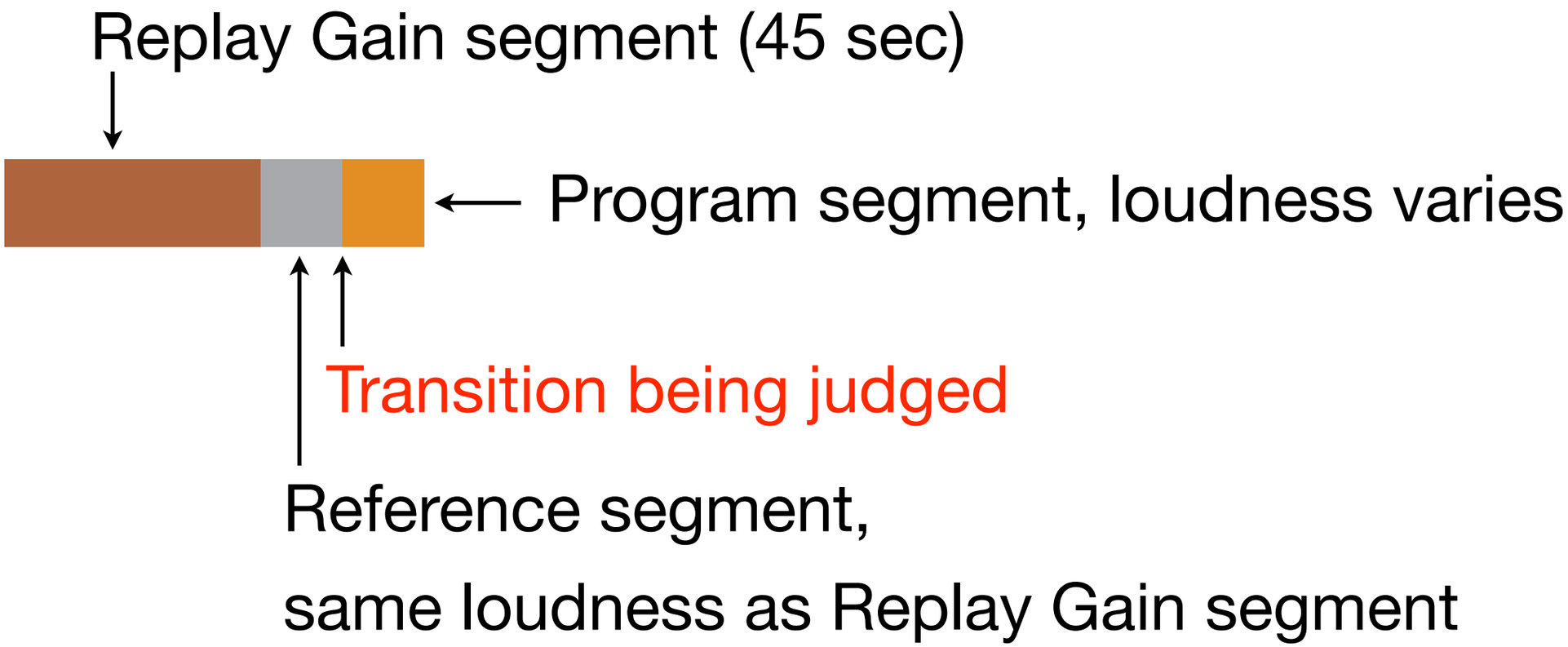
Loudness Jump Tolerance



Each transition is evaluated on a five point scale:

Too Low	Low	Good	High	Too High
would turn up	but would ignore		but would ignore	would turn down

Loudness Jump Tolerance



Loudness Jump Tolerance

Tests with mostly speech

Tests with mostly music and effects

Loudness Jump Tolerance

Results

50% would adjust volume
for a loudness *increase* of 3 LU
for a loudness *decrease* of 6 LU

95% would adjust volume
for a loudness *increase* of 5 LU
for a loudness *decrease* of 8 LU

Conclusions

Any type of sound could trigger a level-adjustment.

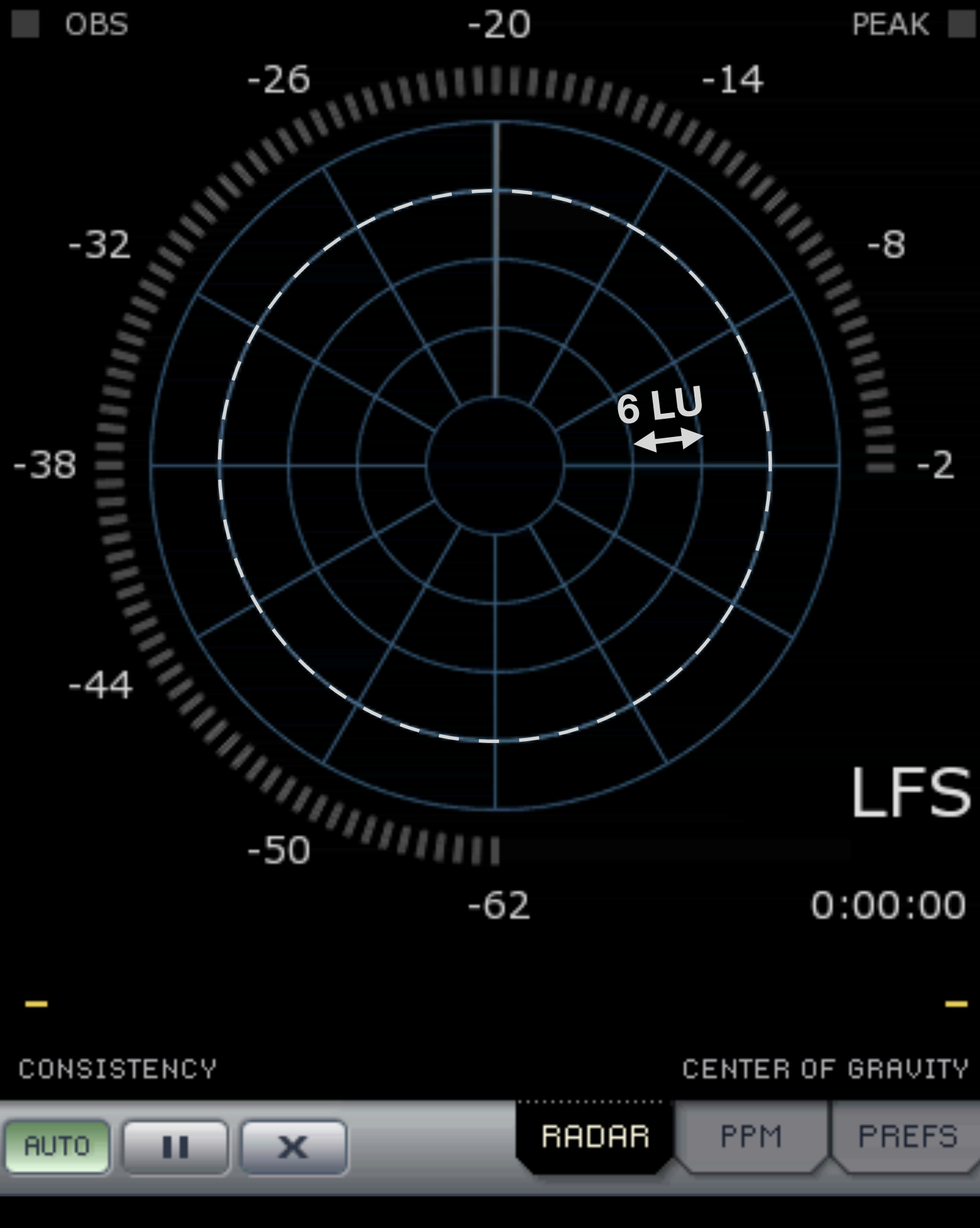
If one program at a junction is WLR, there's a risk of generating an annoying loudness-jump.

Example:

A program transition

most TV listeners

would find annoying



Inter-program Loudness

Zap-test

Statistics based on all possible edit-points using different normalization methods

Programme A	***Programme B***	***Loudness alignment***	***Median loudness-jump (50%), A→B***	***Max loudness-increase (95%), A→B***	***Max loudness-decrease (5%), A→B***
Friends, TV show	Speech, even	FgL	0.8	6.3	-2.5
Friends, TV show	Speech, even	CoG	0.3	6.0	-3.1
Speech, even	Friends, TV show	FgL	-0.8	2.5	-6.3
Speech, even	Friends, TV show	CoG	-0.3	3.1	-6.0
The Matrix, 5.1	Friends, TV show	FgL	10.2	21.0	-5.7
The Matrix, 5.1	Friends, TV show	CoG	7.9	19.0	-8.6
Friends, TV show	The Matrix, 5.1	FgL	-10.2	5.7	-21.0
Friends, TV show	The Matrix, 5.1	CoG	-7.9	8.6	-19.0
The Matrix, 5.1	Speech, even	FgL	11.5	20.9	-4.0
The Matrix, 5.1	Speech, even	CoG	8.8	18.7	-7.4
Speech, even	The Matrix, 5.1	FgL	-11.5	4.0	-20.9
Speech, even	The Matrix, 5.1	CoG	-8.8	7.4	-18.7

Jump should ideally stay below **5 LU** **8 LU**

Inter-program Loudness

Need to find a best possible normalization strategy that works across genres and across broadcast platforms.

Agenda

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Normalization

Optimized and transparent criteria for program normalization (= static gain offset for each program)

A/85 & R128

A comparison between new loudness based guidelines from USA, Japan and Europe

Normalizing *WLR* Programs

A challenge to find a normalization method that works automatically and across genres.

Speech normalized at -24 LUFS

Momentary Loudness

400 ms window

Sliding Loudness

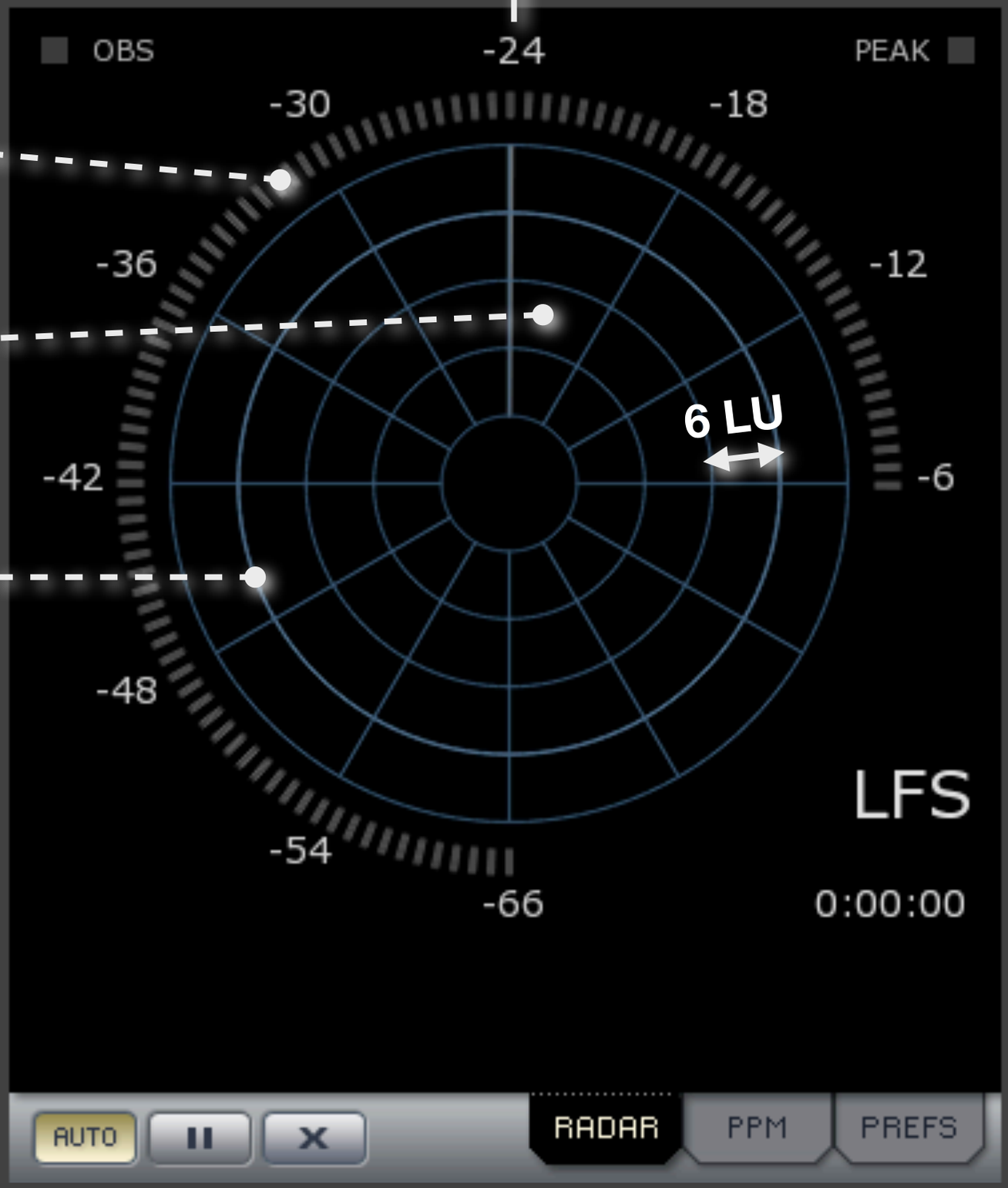
Radar, 3 sec window history

Target Loudness

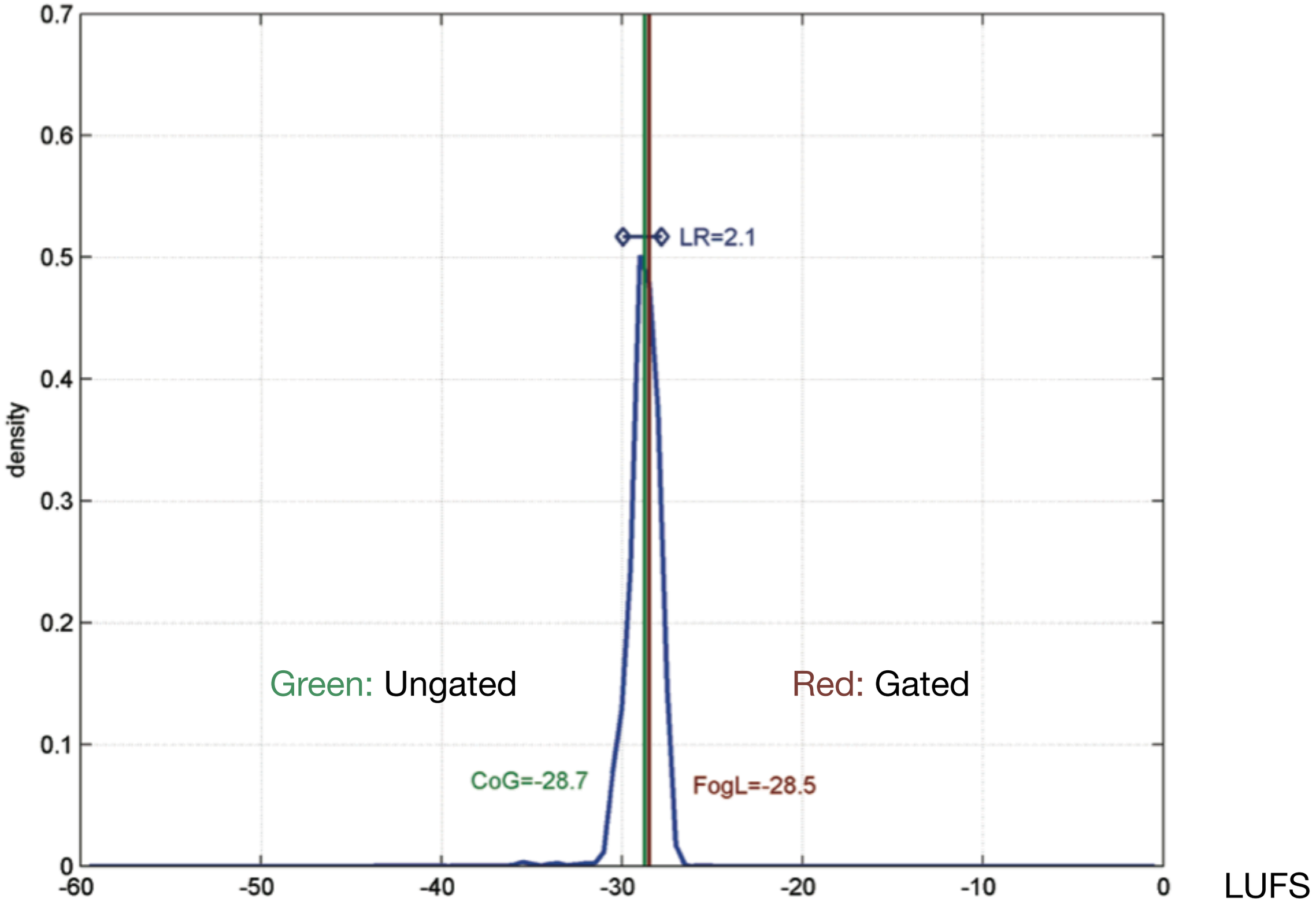
At 12 o’clock and at bold circle

Four Programs:

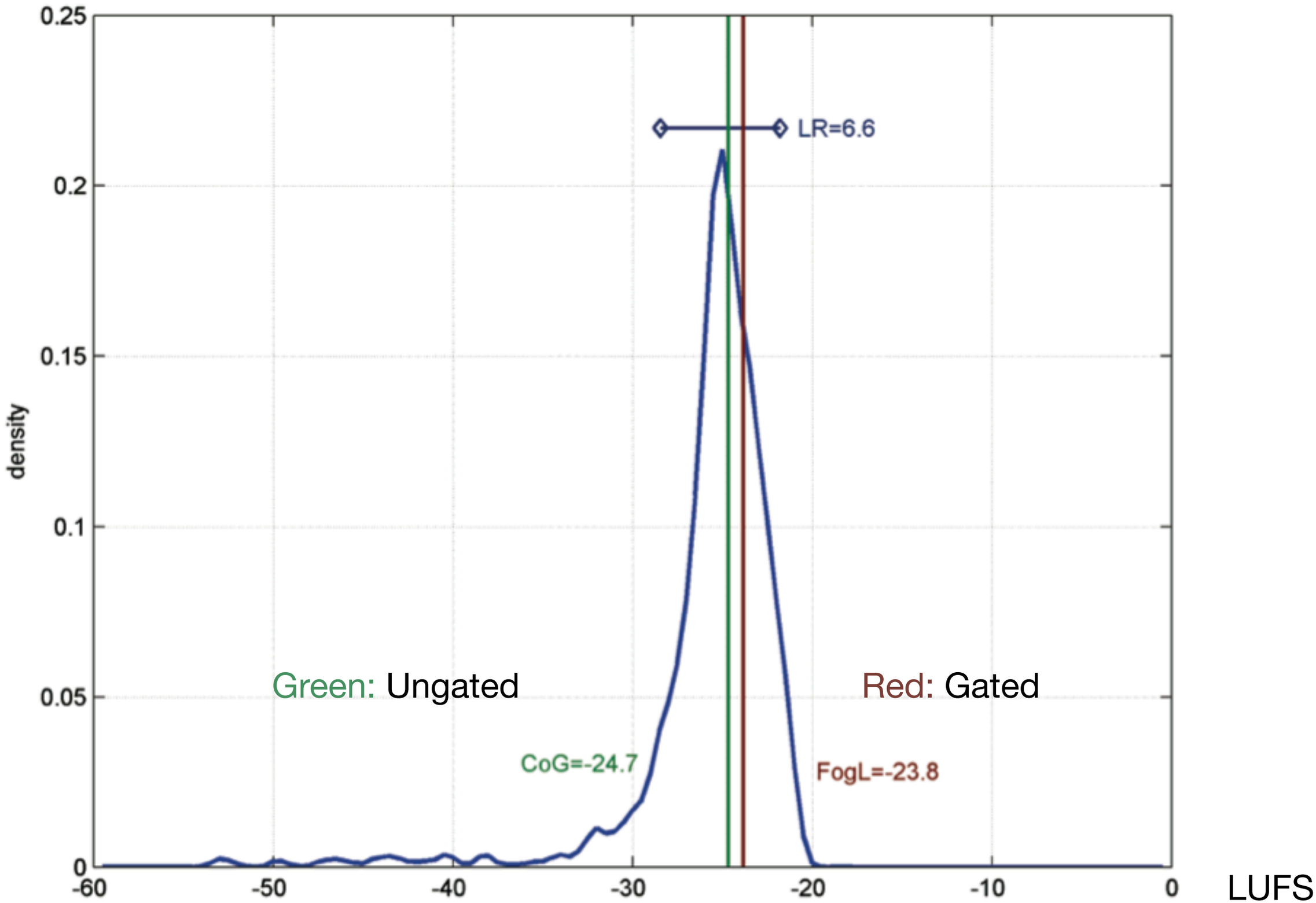
1. Movie
2. Commercial
3. Drama
4. Pop



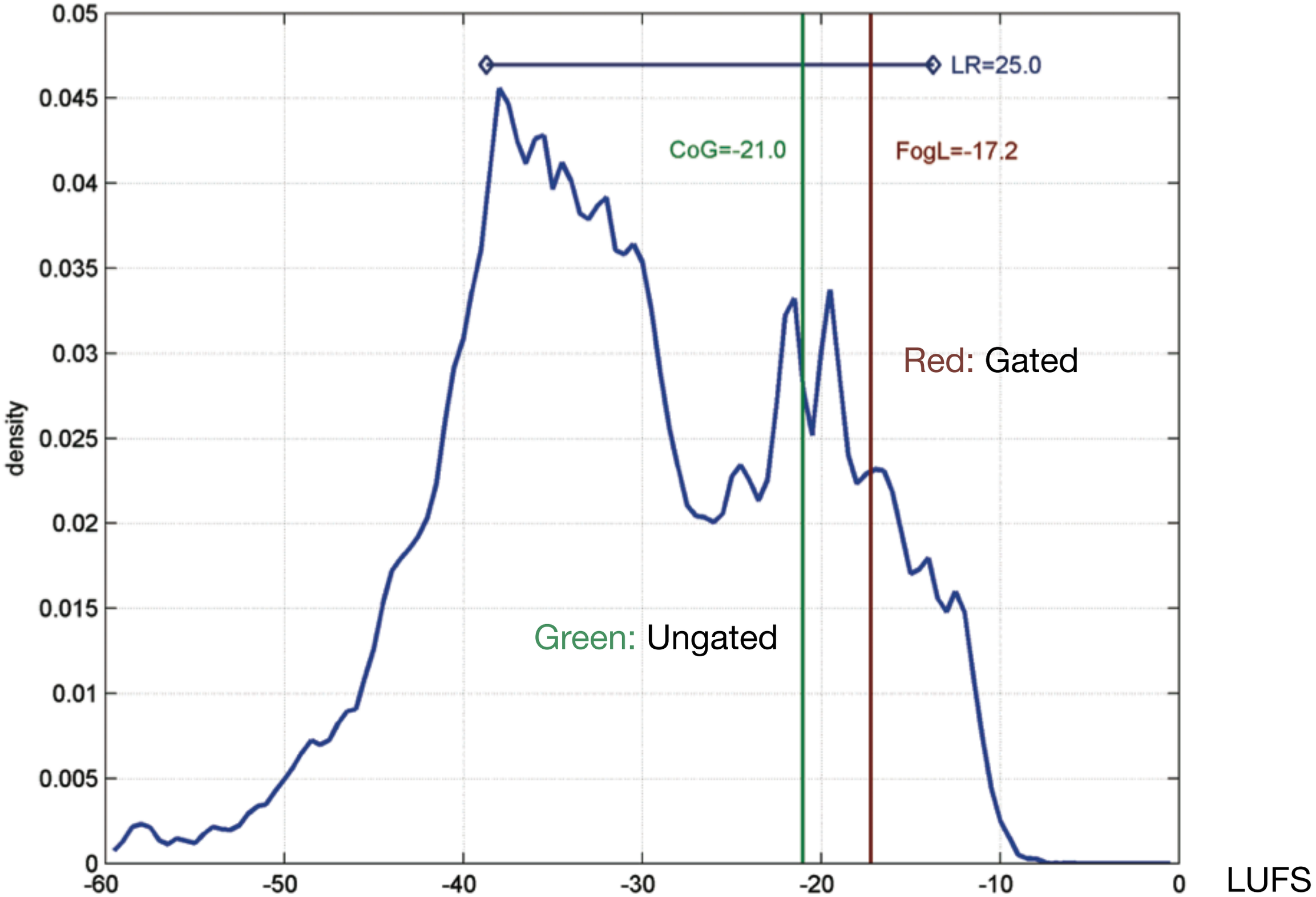
News Speaker (NLR)

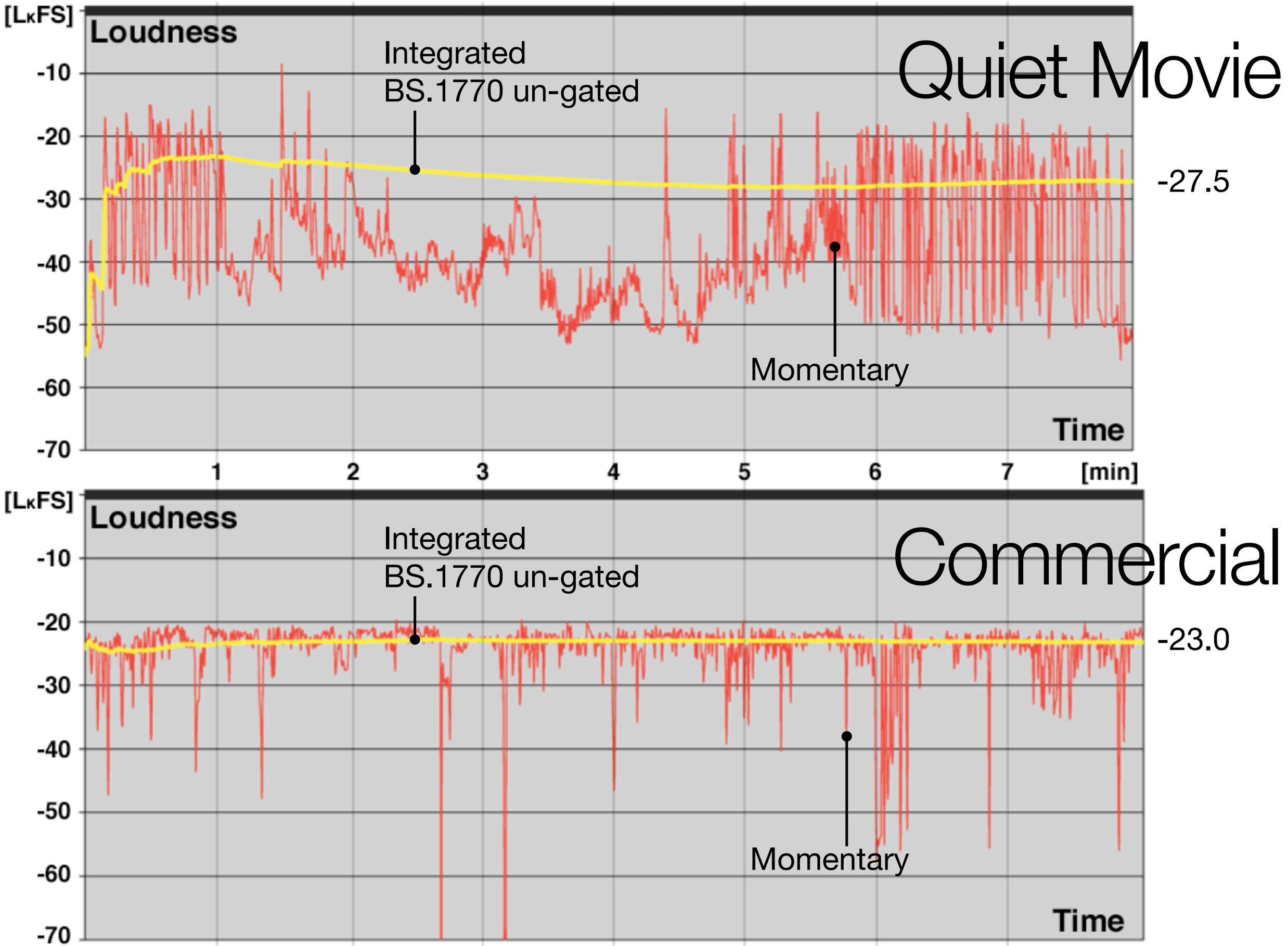


Episode of Friends (MLR)



The Matrix Movie (WLR)



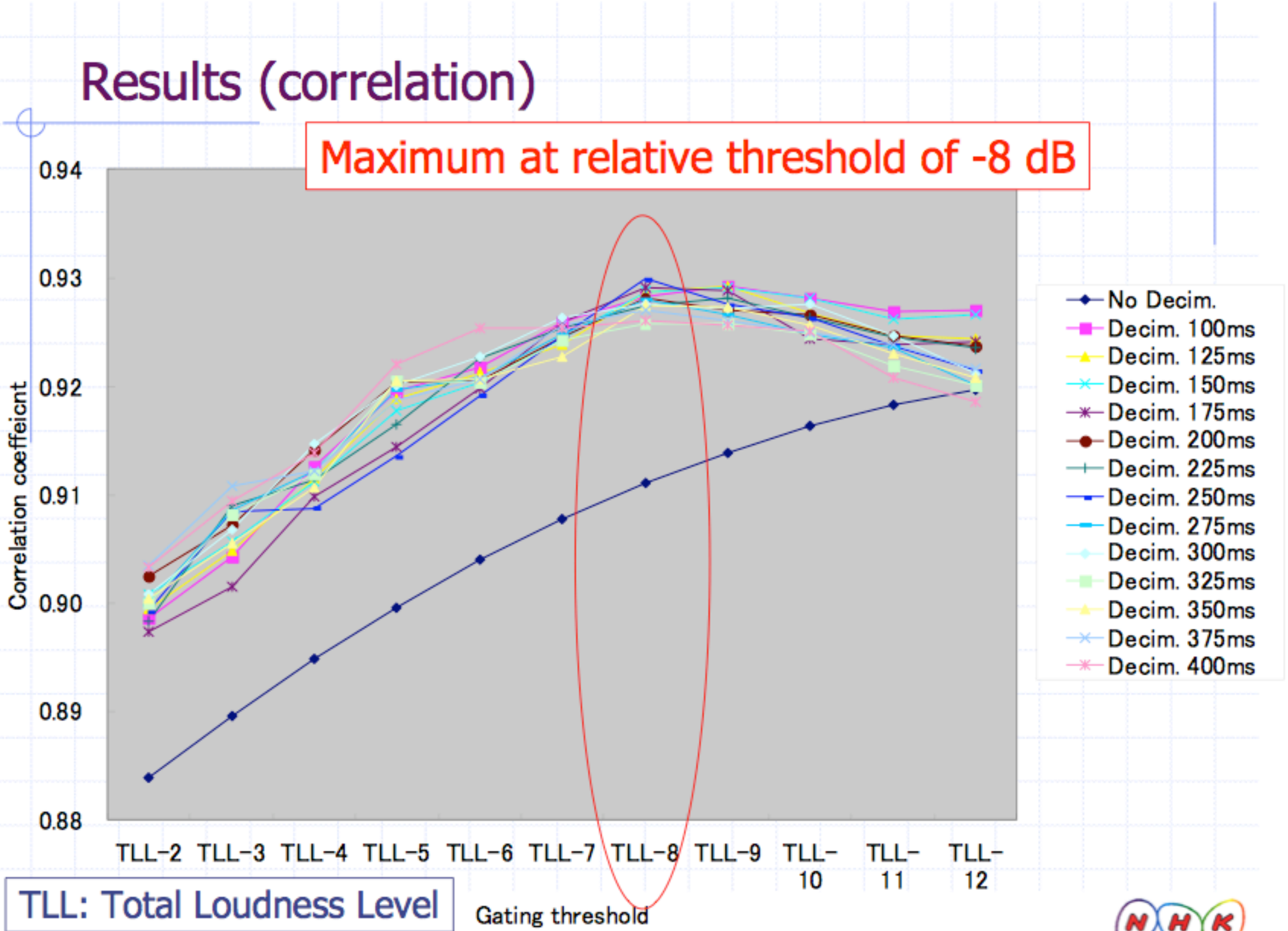

[LKFS]
Loudness
Integrated
BS.1770 un-gated
Momentary
Time
-10
-20
-30
-40
-50
-60
-70
1
2
3
4
5
6
7
[min]
Quiet Movie
-27.5
[LKFS]
Loudness
Integrated
BS.1770 un-gated
Momentary
Time
-10
-20
-30
-40
-50
-60
-70
Commercial
-23.0

Relative Measurement Gate

EBU	A relative gate between -10 and -6 LU gave significantly better normalization results than no gate, or other gating schemes. *R128: Rel. gate at -8 LU.*
Japan	Independent verification by NAB/ARIB **and** by NHK support the rel. gating method and an -8 LU threshold.
CRC	Independent verification: -8 LU rel. gating shows best MSD performance.

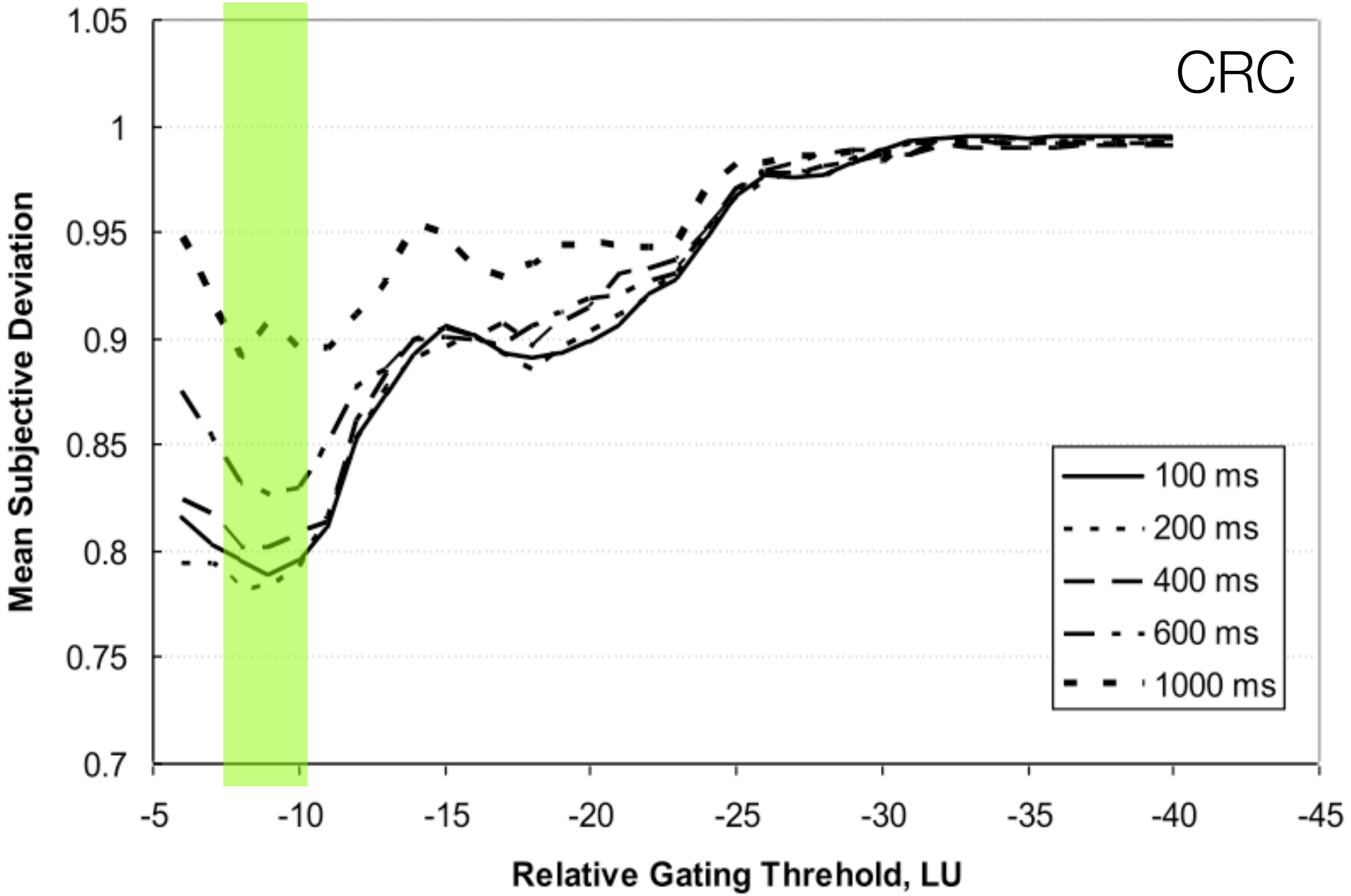
Results (correlation)

Maximum at relative threshold of -8 dB



TLL: Total Loudness Level

NHK STRL


CRC
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
Mean Subjective Deviation
-5
-10
-15
-20
-25
-30
-35
-40
-45
Relative Gating Threhold, LU
100 ms
200 ms
400 ms
600 ms
1000 ms

Normalization iTunes vs EBU R128

The number indicates how much a track is softer (-) or louder (+) with SoundCheck compared to EBU/JP normalization

Track	Deviation [LU]
Homeless, Paul Simon	-4,4
Running To Stand Still, U2	-4,2
Mozart, Quartet in G minor, K. 478, Andante, Brendel	-3,4
Beethoven, Sonata in F Op. 17 Kliegel & Tichman	-2,7
Paris, Texas, Ry Cooder	-2,6
The Bookshop, Monty Python	-2,6
Backyard Ritual, Miles Davis	-2,5
Hotel California, Eagles	-2,4
Slave to The Rhythm, Grace Jones	-2,3
Dirty Blvd, Lou Reed	-2,3
Smile and Wave scene, Madagascar	-2,0
Dude (Looks Like a Lady), Aerosmith (remastered)	-2,0
Church, Lyle Lovett	-1,8
Get Rhythm, Ry Cooder (Johnny Cash)	-1,7
Another Brick in The Wall pt. II, Pink Floyd	-1,6
Don’t Stop (Doin It), Anastacia	-1,5
Rock’n Roll Train, AC/DC	-1,4
2000 Miles, Pretenders	-1,3
Wish You Were Here, Pink Floyd	-1,0
Bach, Goldberg Var, BVW 988 Aria, Andras Schiff	-1,0
Bach, Violin Conc. #2 in E, BVW 1042, Adagio, I Musici	-1,0
Who Will Save Your Soul, Jewel	-1,0
Speak Ref, Sound Check	-0,9
Someone Saved My Life Tonight, Elton John	-0,7
I Just Can’t Wait to Be King, Elton John	-0,7
Bird on a Wire, Jennifer Warnes	-0,7
Nick of Time, Bonnie Raitt	-0,7
She’s a Rainbow, Rolling Stones	-0,6
Fortunate Son, Creedence Clearwater Rev	-0,6

Agenda

Tolerance

Loudness Jump Tolerance predicts when a listener reaches for the remote control

Normalization

Optimized and transparent criteria for program normalization (= static gain offset for each program)

A/85 & R128

A comparison between new loudness based guidelines from USA, Japan and Europe

EBU R128: More BS.1770 Tools

Program Loudness

The **loudness of a full program**.
Relative gate @-8LU.

EBU R128: More BS.1770 Tools

Program Loudness	The **loudness of a full program**. Relative gate @-8LU.
Momentary	**400 ms** measure of loudness. Un-gated rectangular window.

EBU R128: More BS.1770 Tools

Program Loudness	The **loudness of a full program**. Relative gate @-8LU.
Momentary	**400 ms** measure of loudness. Un-gated rectangular window.
Sliding	**3 sec** measure of loudness. Un-gated sliding window.

EBU R128: More BS.1770 Tools

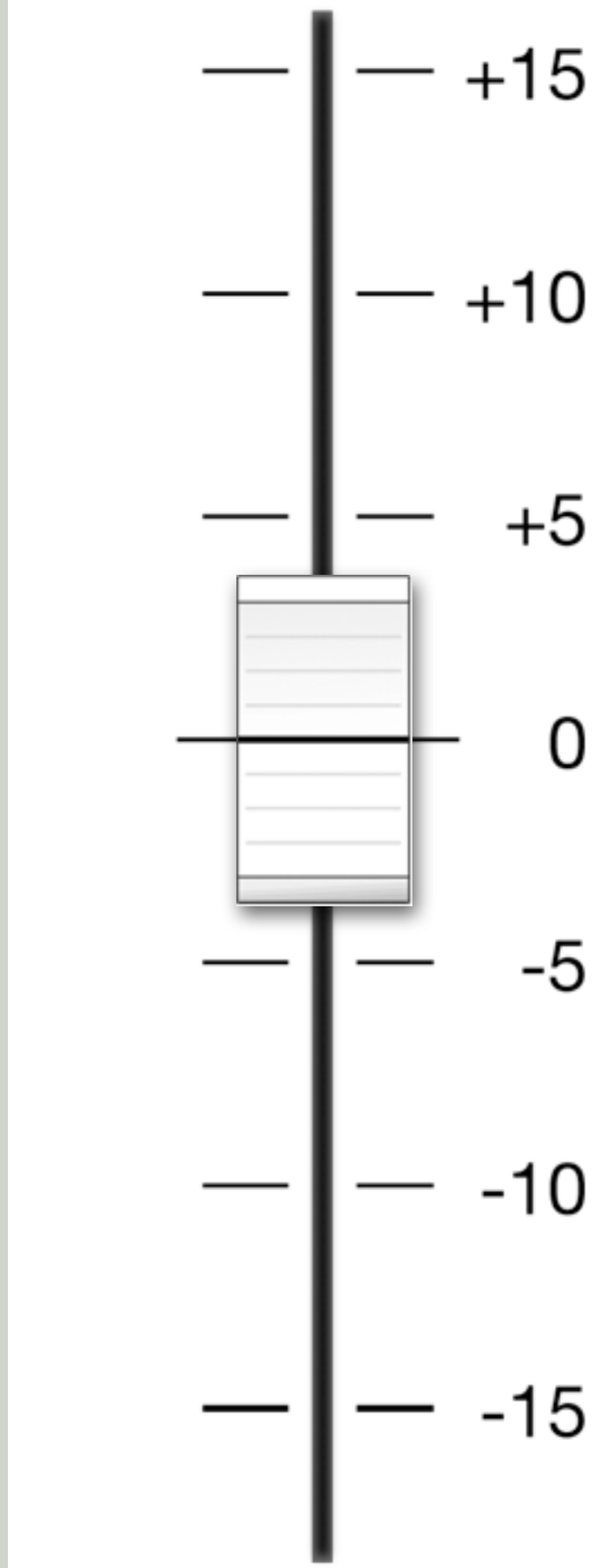
Program Loudness	The **loudness of a full program**. Relative gate @-8LU.
Momentary	**400 ms** measure of loudness. Un-gated rectangular window.
Sliding	**3 sec** measure of loudness. Un-gated sliding window.
Loudness Range	The **loudness variations of a program**. Independent of absolute level.

Loudness Range

Example:

LRA = 10 LU

To keep a **constant** loudness during the program, a +- 5 dB fader gain ride would be required.



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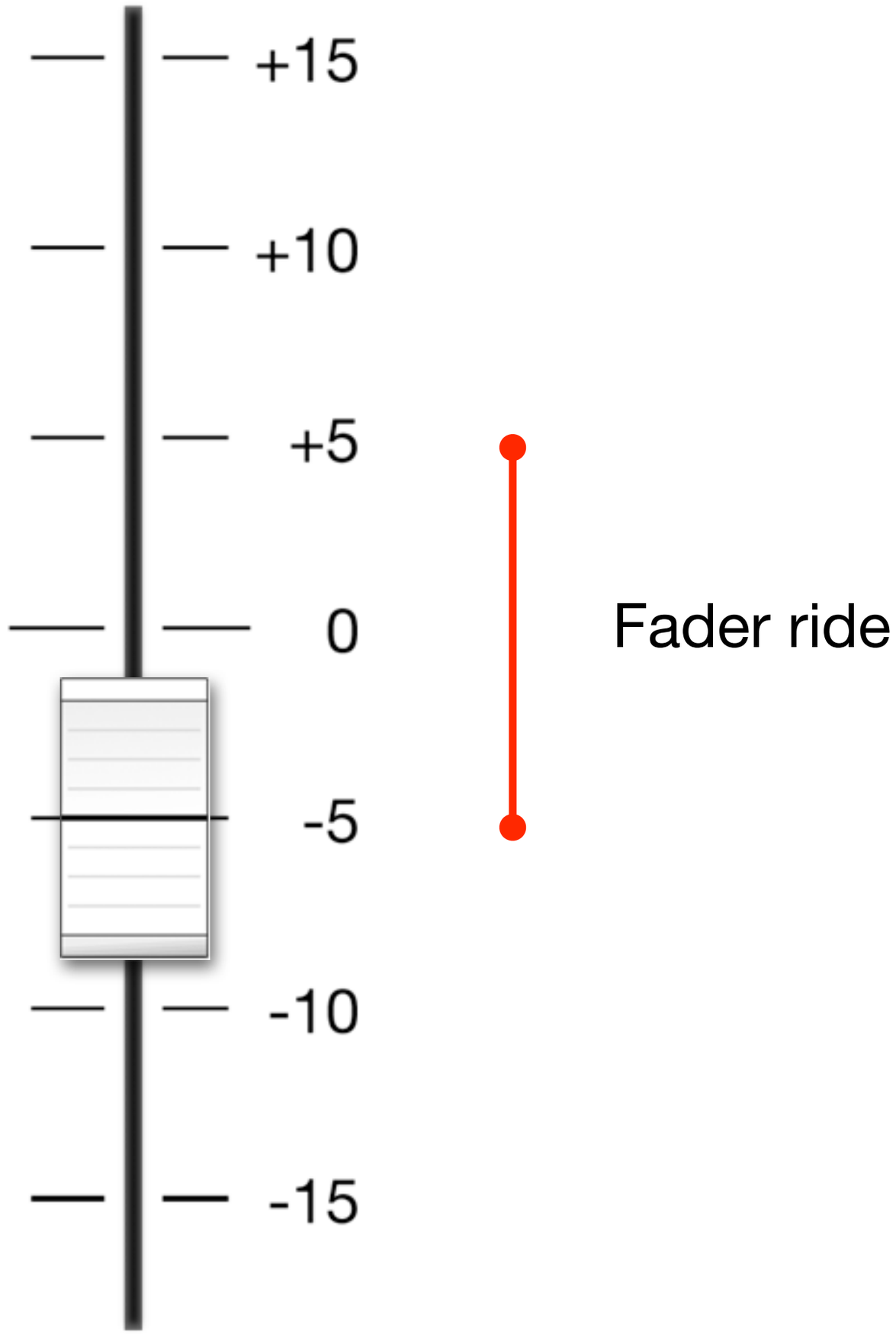

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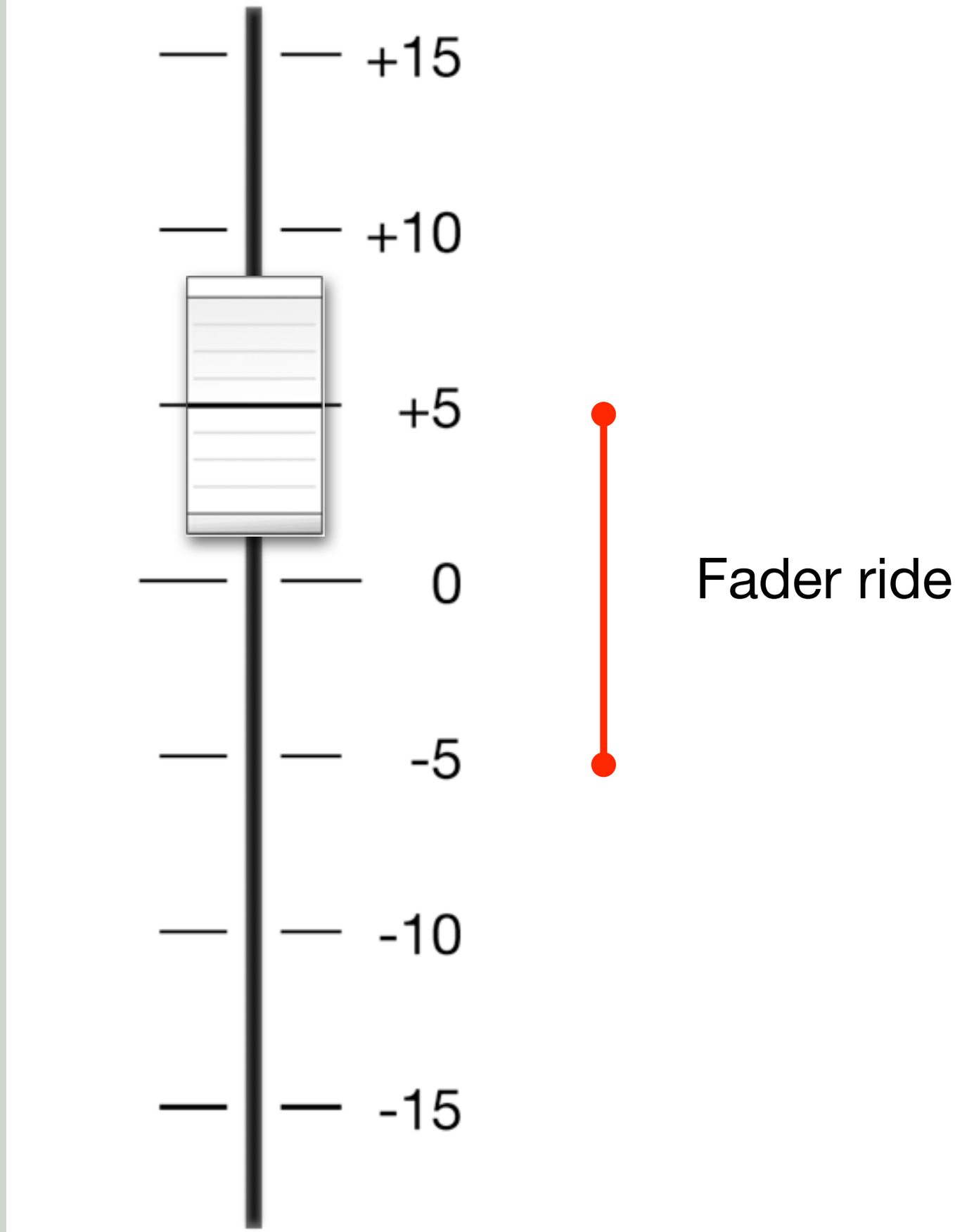


Track	Un-gated	G8	LRA
Wish You Were Here, Pink Floyd	-19,5	-17,3	22,2
Child In Time (Live), Deep Purple	-17,1	-15,3	19,8
Gilgamesh, Battle of Titans, Osaka Symphony	-16,6	-14,5	19,7
Land of Hope and Glory, BBC Orchestra, Proms	-17,6	-16,6	18,7
The Other Side, Pendulum	-14,1	-13,3	16,7
Running To Stand Still, U2	-21,4	-20,5	16,0
Stairway to Heaven, Led Zeppelin	-16,8	-15,7	15,5
Someone Saved My Life Tonight, Elton John	-18,2	-17,0	15,4
Mozart, Quartet in G minor, K. 478, Andante, Brendel	-20,8	-19,7	14,5
C'Era Una Volta Il West, Ennio Morricone	-15,8	-15,0	13,2
Hotel California, Eagles	-19,3	-18,7	12,8
Beethoven, Sonata in F Op. 17 Kliegel & Tichman	-19,7	-19,0	12,0
Paris, Texas, Ry Cooder	-19,8	-18,9	11,0
Bach, Goldberg Var, BVW 988 Aria, Chen Pi-hsien	-17,2	-16,6	10,4
Backyard Ritual, Miles Davis	-19,3	-18,8	10,3
NBC prog sample (all 3:30)	-17,3	-16,8	9,5
Church, Lyle Lovett	-18,5	-18,1	9,3
Slave to The Rhythm, Grace Jones	-18,9	-18,6	8,5
Another Brick in The Wall pt. II, Pink Floyd	-18,5	-17,9	8,5
Bittersweet Symphony, The Verve	-14,8	-14,4	8,4
Homeless, Paul Simon	-21,4	-20,7	8,3
Dirty Blvd, Lou Reed	-18,9	-18,6	8,3
Angel from Montgomery, Bonnie Raitt	-16,1	-15,7	8,3
The Bookshop, Monty Python	-19,8	-18,9	8,2
Always Look On the Bright Side of Life, Monty Python	-16,5	-16,2	8,1
Bach, Goldberg Var, BVW 988 Aria, Andras Schiff	-17,8	-17,3	8,0
I'm Yours, Jason Mraz	-13,9	-13,6	8,0
Bakerman, Laid Back (S. Wolter version)	-12,5	-12,1	7,8
I Just Can't Wait to Be King, Elton John	-17,1	-17,0	7,7

Loudness Range

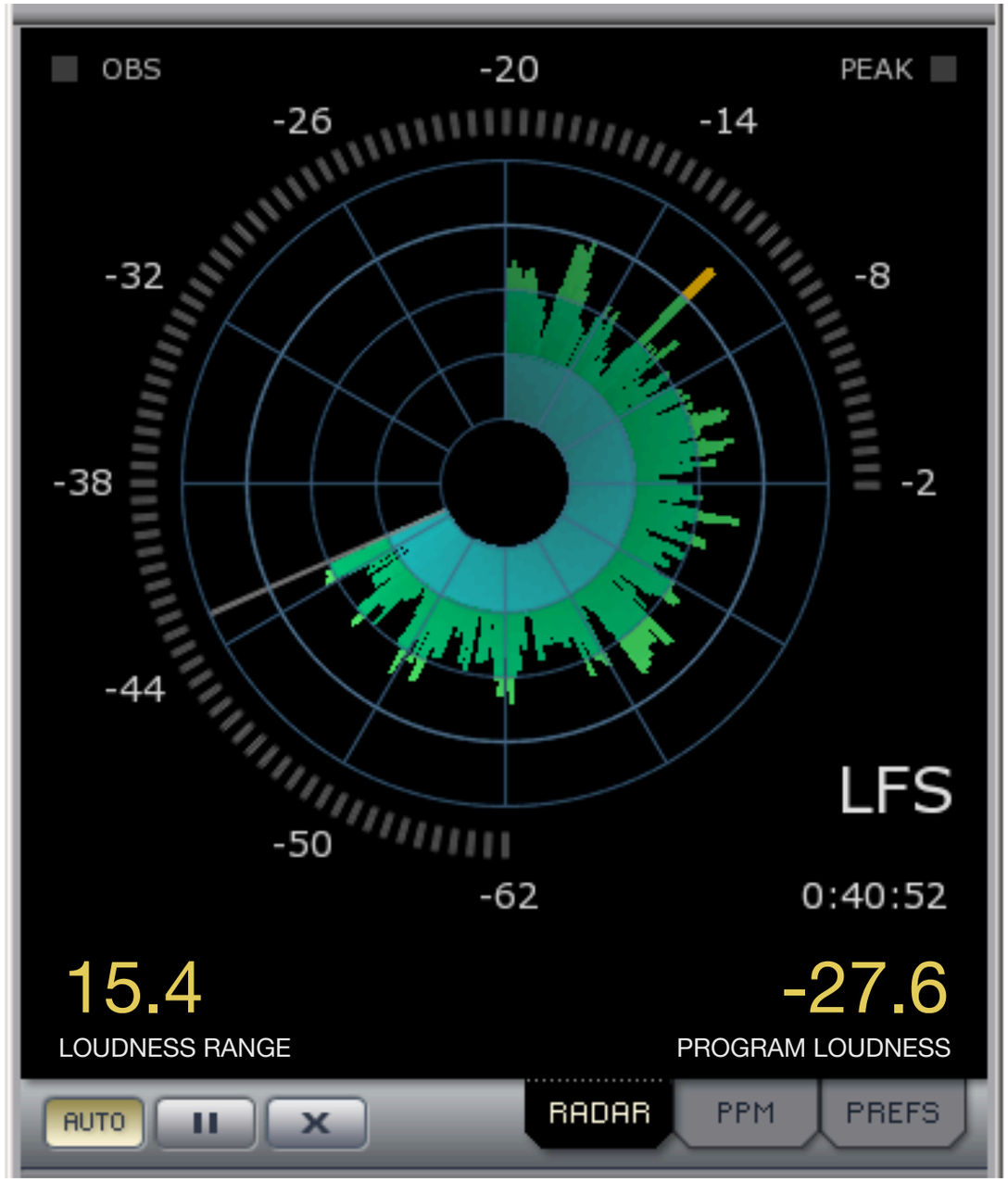
Delivery Specs	Production guideline: Expectations.
Compatibility	Loudness Range predicts if a program fits consumer requirements. **Theatrical TV**: Below 20 LU **Casual TV**: Below 12 LU **Mobile TV**: Below 8 LU
Fingerprinting	To check downstream signal-path incl. satellite, cable and STB.

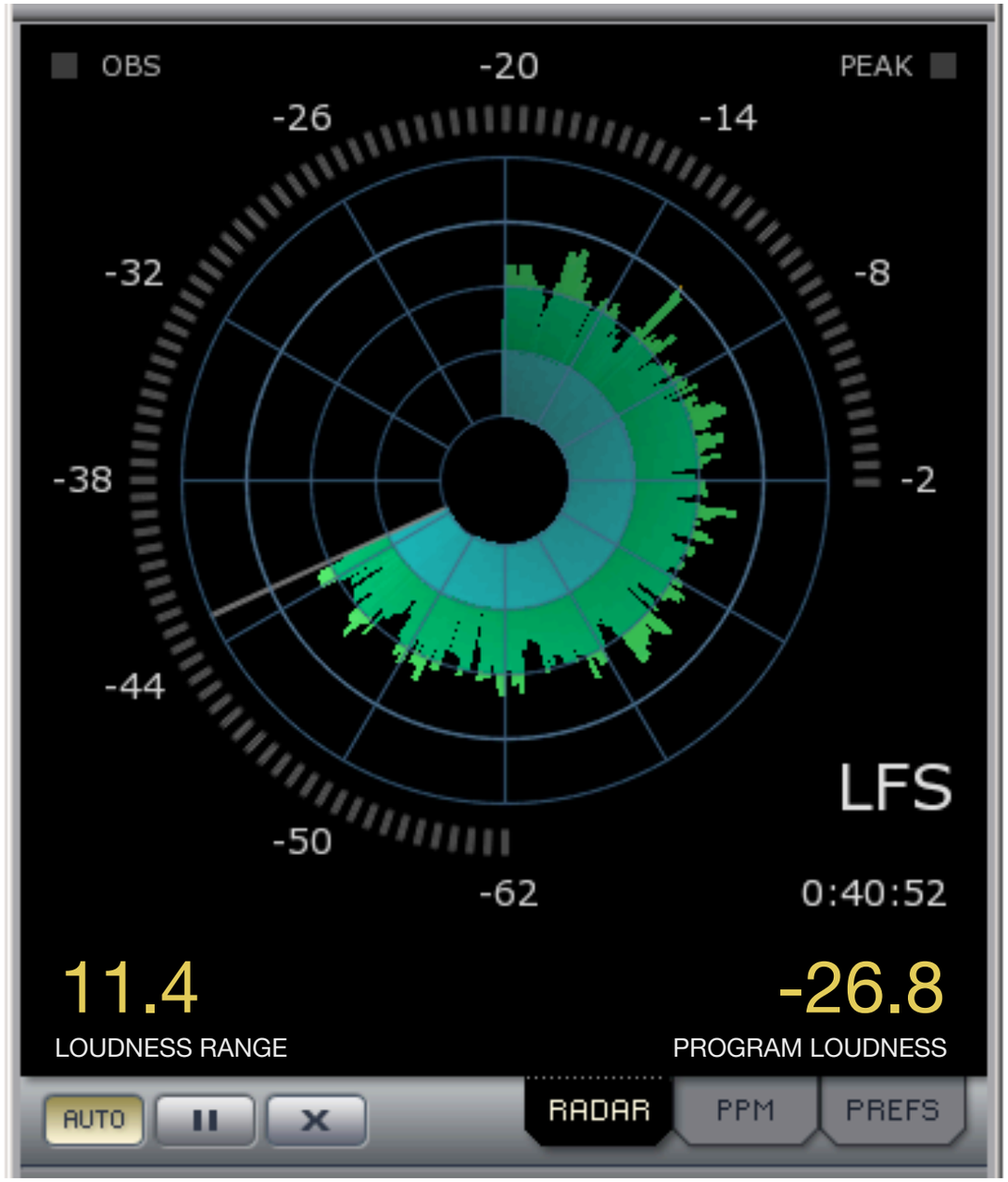
Loudness Range: Fingerprinting

DRC forced off

DH episode 13 season III

DVD and STB





Less than 2% of listeners

More than 98% of listeners

Production Guidelines

Speech	Regular speech: -27 to -23 LUFS
Music	Foreground: -24 to -21 LUFS
Loudness Range	Get expectations corrected early
True-peak Level	Stay below -1 dBTP May need further lowering downstream depending on transmission format

Production & Live metering

Should be BS.1770 compliant

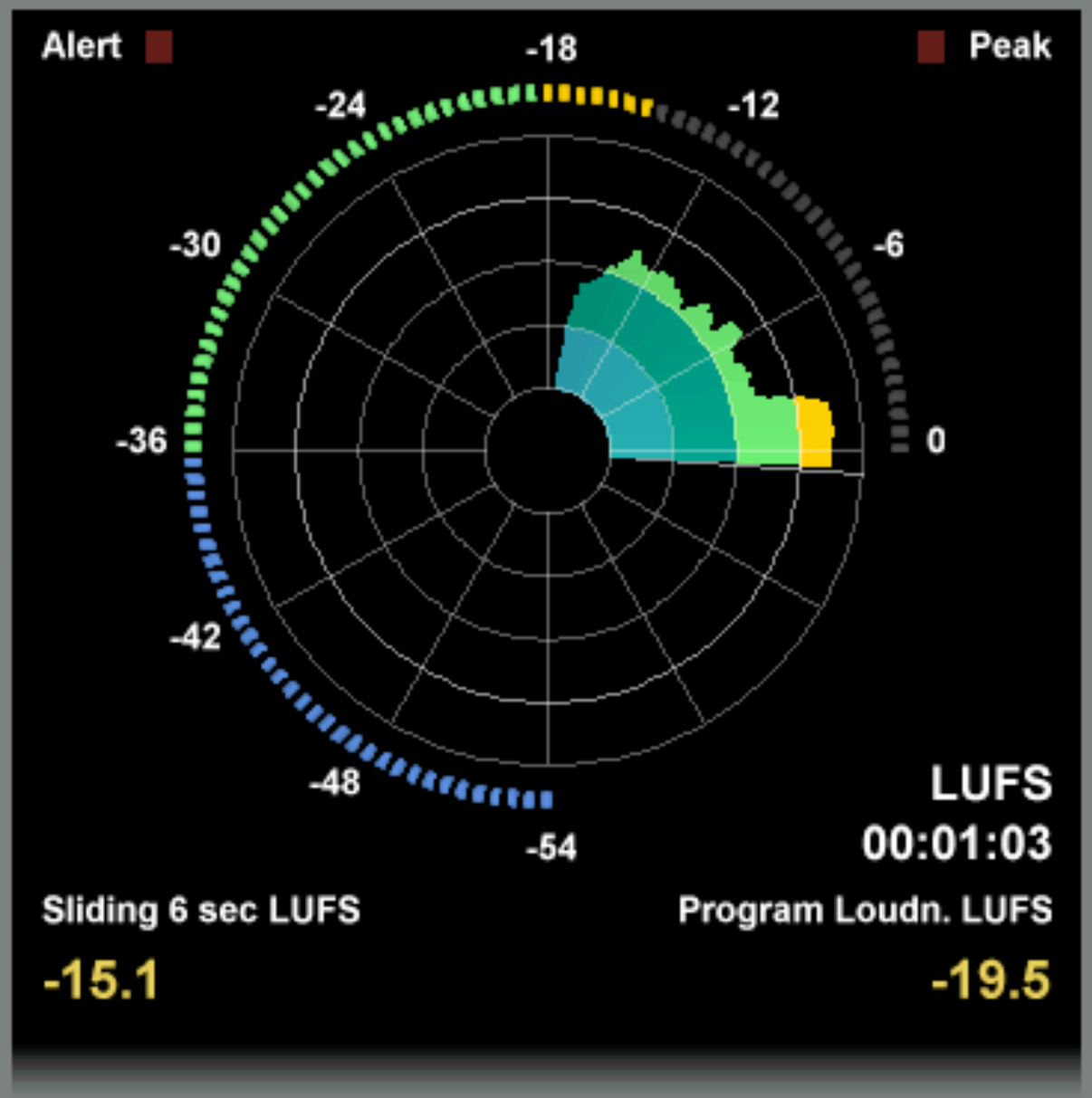
Mixing by numbers

Graphical approaches

Definitions in EBU R128

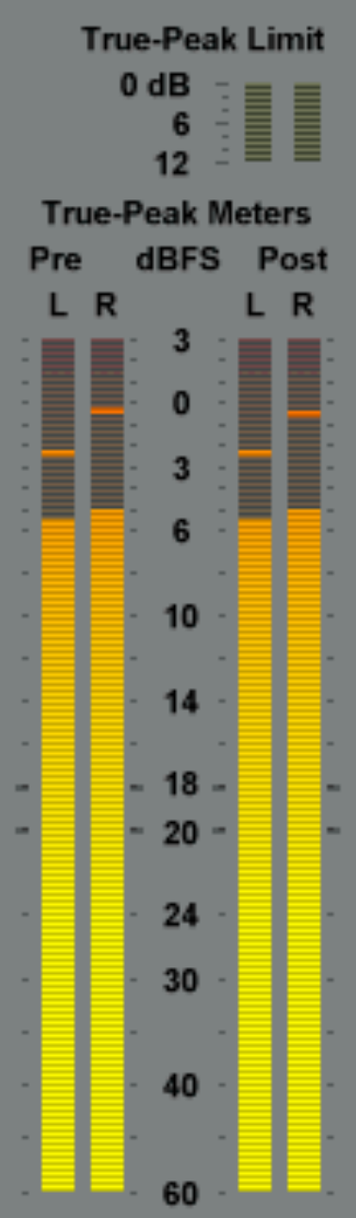
Library | System | Engine

Edit | Main | Log | Setup | Stats | Bypass | Radar | Pause | Fader Asgn | Reset



True-Peak Limit
0 dB
6
12

True-Peak Meters

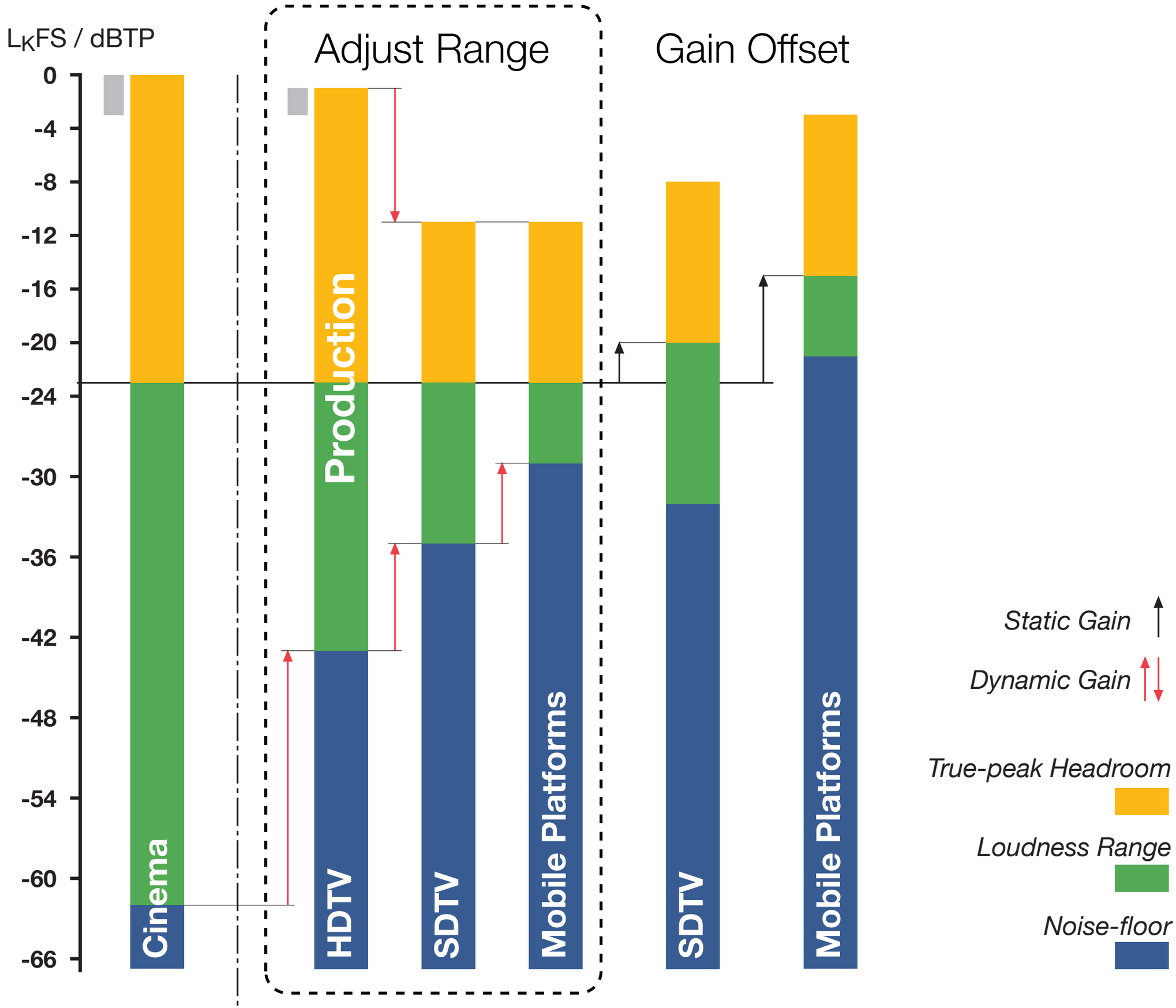


Target	Radar Resolution	Radar Speed	Descriptor 1	Descriptor 2
-18.0 LUFS	6 dB/div	4 min	Sliding Loudn.	Program Loudn.

“Mixing by numbers”

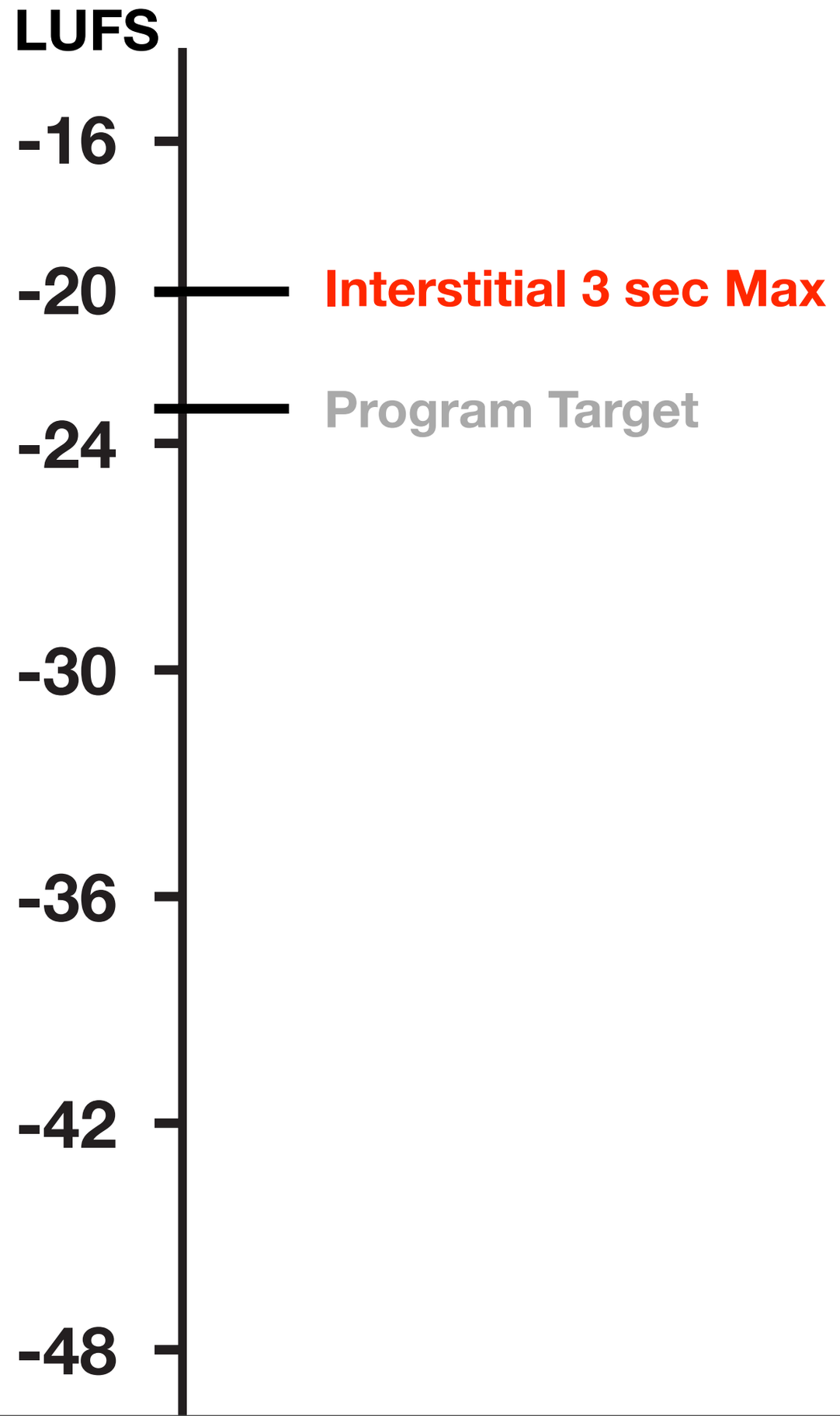
Transmission Guidelines

Normalize	Normalize programs *at the station*. Max loudness rule for interstitials.
Metadata	Use static metadata. Change *only* if switching between stereo and 5.1. Enter Target as dialnorm number. *Remember how the decoder in AC3 is not speech centric. Dialnorm only tells the average level of the program.*


L_KFS / dBTP
0
-4
-8
-12
-16
-20
-24
-30
-36
-42
-48
-54
-60
-66
Adjust Range
Gain Offset
Production
Cinema
HDTV
SDTV
Mobile Platforms
SDTV
Mobile Platforms
Static Gain
Dynamic Gain
True-peak Headroom
Loudness Range
Noise-floor

Interstitial

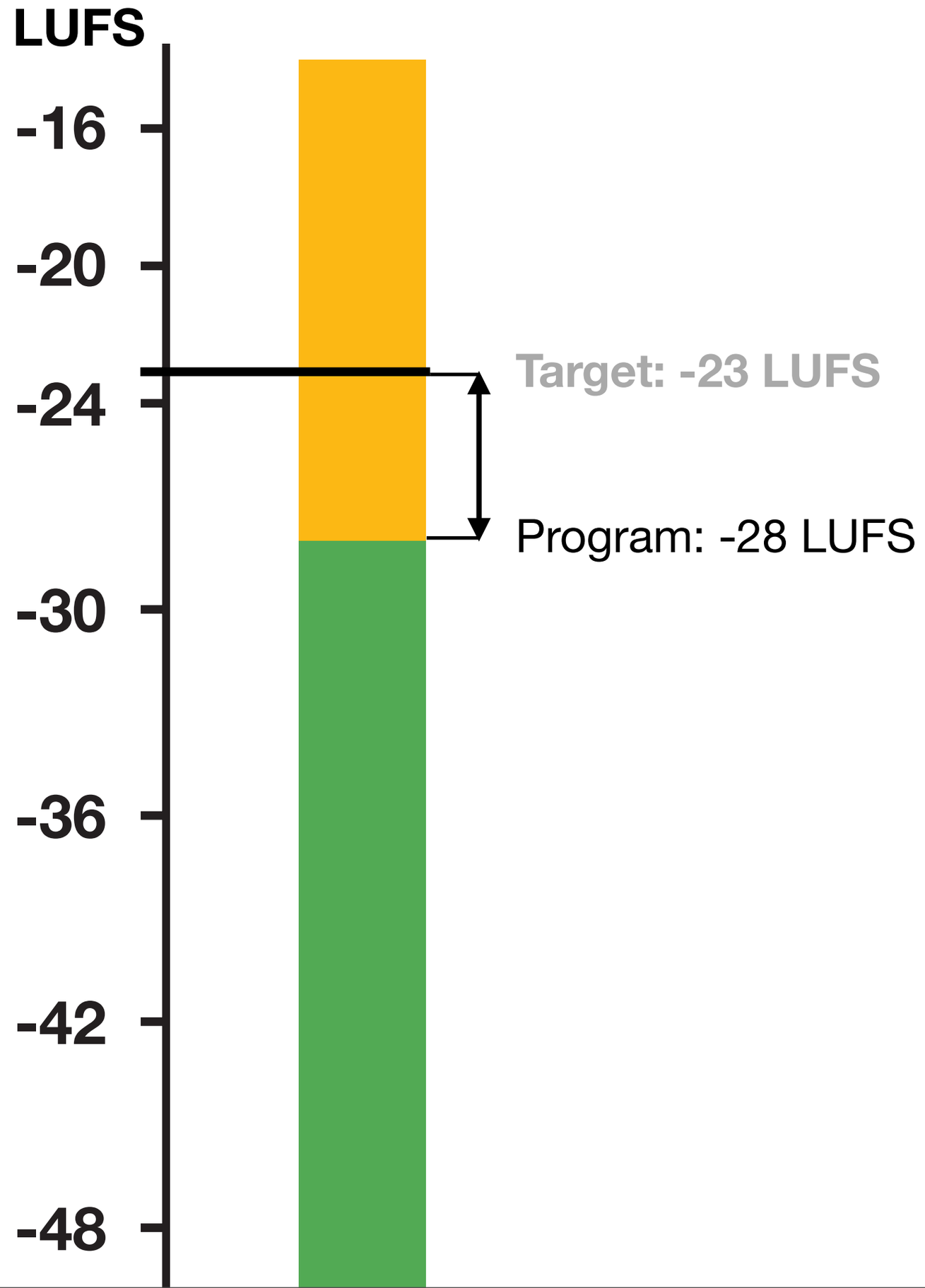
2nd line of defense



Interstitial

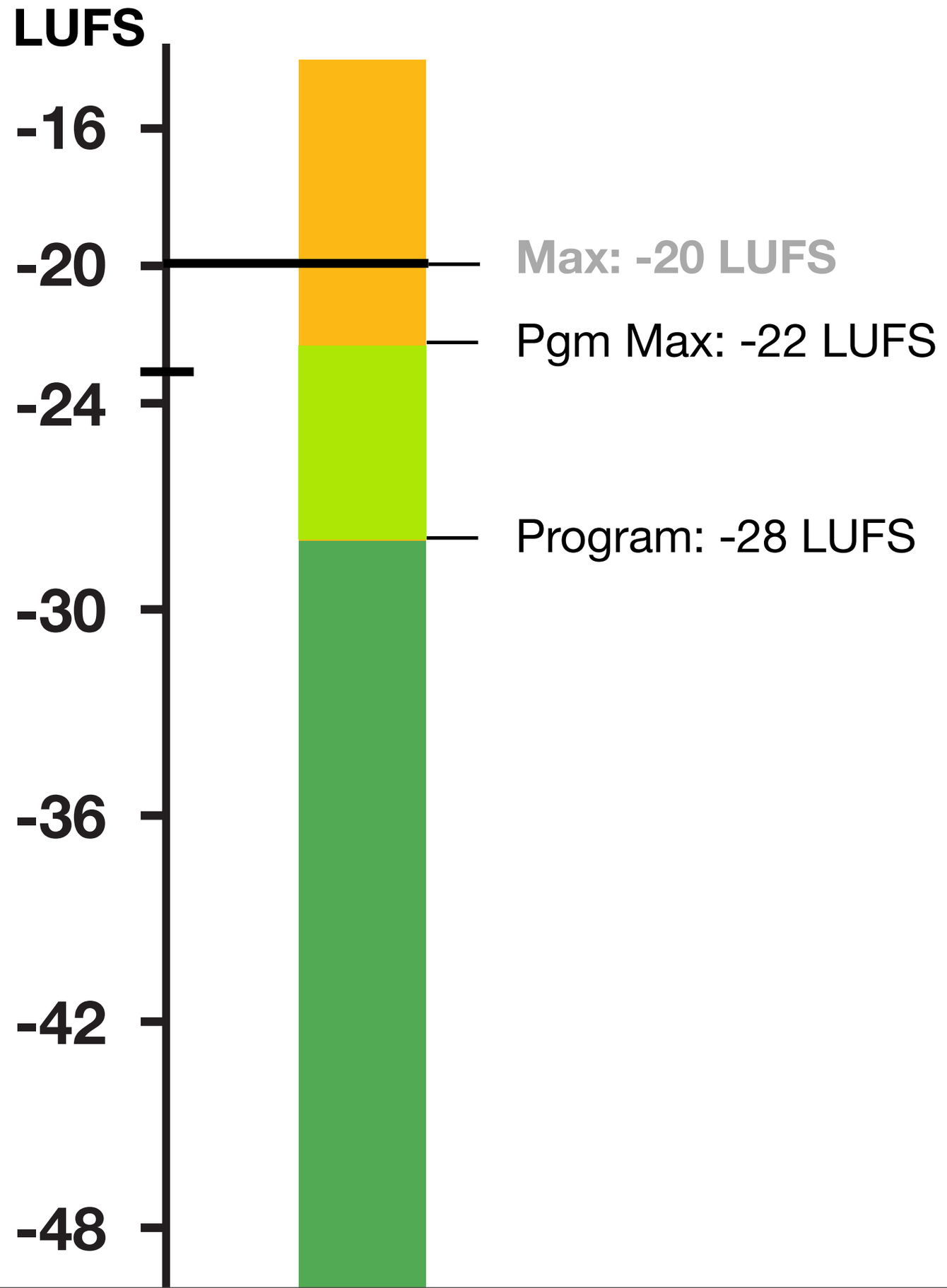
2nd line of defense

Normalization rule
suggests +5 dB gain



Interstitial

2nd line of defense

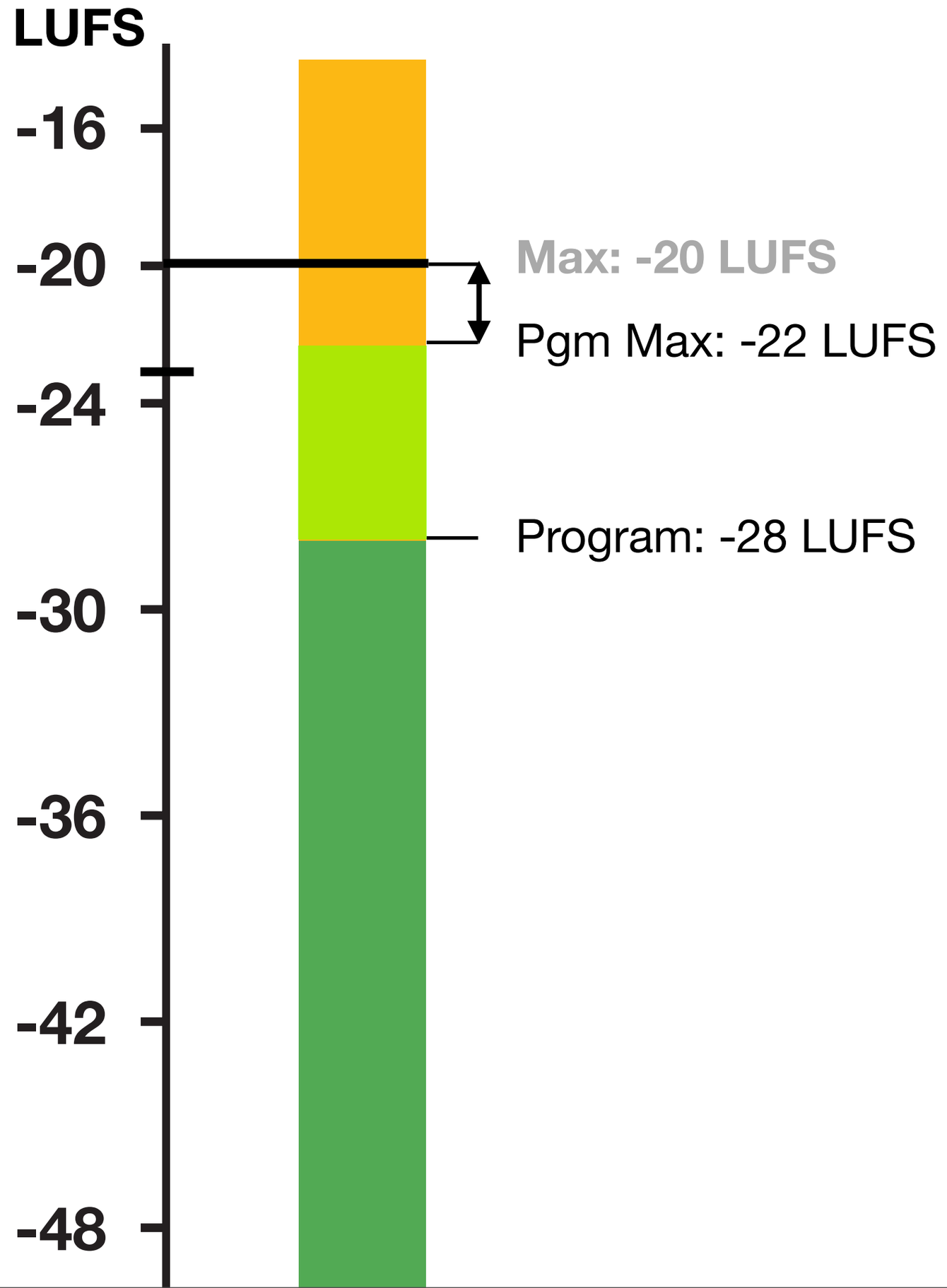


Interstitial

2nd line of defense

Loudness Max in this case prevents a full boost

Result: +2 dB



Program Loudness

Un-gated	G20	G8
Includes silence	Excludes silence	Focus on foreground
Application critical	Application friendly	Application friendly
Cross-genre critical	Cross-genre critical	Cross-genre friendly

Expect similar numbers with NLR material

Expect different numbers with WLR material

Common understanding: Loudness instead of Peak level

A/85

Luxurious HDTV Focus

Anchor for WLR

Great Monitoring guidelines

AC3 manual

R128

All Platforms

One Number

Distribution guidelines

Open standards

Harmonized metering

Tools to control commercials

Ugly Examples

1. **Danish Pop** **-7.2 LKFS**
2. **Kelly Clarkson** **-4.2 LKFS**
3. **Metallica** **-3.0 LKFS**
4. **Pink Noise (FS)** **-8.7 LKFS**

References

Continued Reading

Zwicker & Fastl, 1990
Psychoacoustics - Facts and Models

Moore et al., 2003 (JAES no 12)
Why are Commercials so Loud?

Nielsen & Lund, 1999 - 2006 (AES 23, 107, 109, 111, 117, 121)
0 dBFS+ Level in Mastering and Audio Production

Skovenborg & Lund, 2008-2009 (AES 125, 127)
Loudness Descriptors to Characterize Programs and Music Tracks

Grimm, Skovenborg & Spikofski, 2010 (AES 128)
Determining an Optimum Gated Loudness Measurement for TV Sound Normalization

ITU-R BS.1770-1, ATSC A/85, EBU R128

End

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