Objective Reading of Loudness of a Sound Programme

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OBJECTIVE READING OF LOUDNESS OF A SOUND PROGRAMME

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ABSTRACT

An objective measure for audio level loudness is increasingly required by broadcasters in order to produce a homogenuos sound surface. Current international standards for PPM's (Peak Programme Meters) is inadequate for the indication of audio loudness. 30 years ago, ISO[1)] issued a specification that would produce an objective value of the equvivalent loudness of an audio signal. This specification has only had limited impact due to its complexity of implementation. By means of DSP technology, a low-cost, simple-to-operate system has been developed and implemented on a standard metering system.

BACKGROUND

In radio, television and in the recording industry the audio reference levels are defined purely from an electrical point of view. A range of international standards covers the electrical, mechanical and optical specifications, for meters suitable for audio level control. Recently all domestic standards has been unified by the IEC in the specification IEC 268-[(2]. With the addition of the German IRT Pflichtenhefte[(4] almost all meter requirements in Europa is covered. Basically the German specification has a few extensions to the IEC specification, but in general application the meter indications are identical.

When first developed 30-40 years ago the main purpose of the standards were to standardize the level meter indication in order to obtain a unified level reading from all audio installations independently of origin of manufacture or country. You will recall, that in those days all audio signals were analogue processed and recorded. The design criteria for the electrical behaviour was to permit maximum electrical signal level without noticeable distortion.

Fig.1 shows the block schematic of a typical PPM (Peak Programme Meter).

The PPM concept is still the compulsory requirement by broadcasters in Europe. It is important to notice, that the PPM concept will suppress indication of audio peaks even at system clipping level, if the duration of the peak is short. A few areas in Europa will specify VU[(3] indication. In general a VU reading level meter will provide no information about the peak signal level in a audio circuit.

DIGITAL AUDIO PROCESSORS AS LOUDNESS CONTROL

With the current recording, distribution and transmission systems, high peaks, if left unattended, will lead to serious problems in terms of overloading and distortion phenomenas. Consequently, the output of all audio systems are sourced through a multi-band compressor/ limiter system. The characteristics of these units are not standardized, but mostly covered by proprietary protection. The main design criteria is to provide the highest possible audio signal without causing succeeding electrical overload.

Sophisticated digital processors can develop a remarkably higher audio loudness without exceeding the maximum permitted signal level. As a consequence digital post-processed audio material will have a significantly higher loudness than analogue audio material. Please note that the current metering systems will not indicate the increased energy accordingly.

SEE WHAT YOU HEAR

In principle the audio balance of the individual programme items should be determined by the producer at the time of recording. Later, when transmitted, level changes should not be necessary.

However, in praxis this is not working. Producers and tone engineers produce programs with uneven loudness, because at present they have no tools that will display objective information about the loudness.

As a result we have an instant complaint about the increased loudness of commercials in television. The loudness of commercials are noticably higher than the average loudness of the broadcasted signal. The need for an audio meter to provide an objective value for the loudness, is an obvious requirement in order to obtain a homogenuos audio loudness level.

PIONEER WORK BY 'DANSK REKLAMEFILM'

A similar problem has been delt with by Dansk Reklamefilm. All cinemas in Denmark are supposed to reproduce the film sound track on equal conditions in order to optimize the experience of a movie. The absolute sound pressure level in the theater is essential to the overall experience, and all volume controls are set after careful alignments. Before the 1st of January 1995 the audio level on commercials were merely determined by the clipping level of the optical reproduction system, because the advertersers wanted to expose their own product on behalf of the audio quality. This fact was unsaticfactory for the audience since they did not receive the high quality audio that they expected, and had indeed paid for. Remember, commercials in cinemas are considered to be a part of the performance and not an undesired intermezzo.

A specification was developed and implemented by the parent film commercial organization 'Dansk Reklamefilm'[5] in order to get full control of the loudness of the compiled commercial surface. The specification has been sucessfully implemented in practice and the audio reproduction quality in the film theaters has been improved dramatically. Fig. 2 shows the level recorder system. Fig. 3 is a sample copy of a level recording. Similar systems are in service in several European countries.

PARAMETERS THAT INFLUENCE THE LOUDNESS JUDGEMENT

Fortunately the human ear and brain are excellently geared to process an audio signal. Everything we try to do with computers will only be coarse approximations. A lot of factors has an influence when it comes to the judgment of loudness.

Measureable parameters:

- Absolute Sound Pressure
- Frequency Distribution
- Duration of the Sound

Psychologic parameters:

- Environment
- Appeal of programme
- Audio Quality
- Audio Experience
- Time of Day
- Mental Condition
- Age
- Sex

The measureable parameters can be processed by a computer system, whereas the psychological parameters only can be handled by a human. As an example most people will probably consider a `Heavy Metal´ recording to be quite loud in the early morning. Only long, general experience of operation in a broadcasting station can take the psychological parameters into account.

PERCEPTION OF AUDIO

As earlier stated the perception of audio is different from human to human, and it is very difficult to provide a unified expression. However, there are some characteristic behaviour which will be identified: The perception of clean tones, noise masking effect, frequency sensitivity and the response time of the ear.

It is not the scope of this paper to give an in depth explanation of all these parameters, but those who find that of particular interest should seek more information in the references given below.

PERCEPTION OF CLEAN TONES

A tone is characterised by the frequency and the intensity. Audible tones should be in the range 20Hz to 20kHz, and in the range of 120 to 0 dB all depending on age. Furthermore, the ears sensitivity vs. frequency is not linear. A set of contours of equal-loudness is defined in ISO 226 (Fletcher and Munson).

The relationship between the subjective perception of the loudness and the loudness in Phones is described in ISO 131.

NOISE MASKING OF CLEAN TONES

When two or more audio signals are present a masking effect take place. The masking is closely related to the physical aspects of the human ear. We define different kind of audio masking effects: complete masking, partial masking, pre- and post masking. All described by E. Zwicker in his comprehensive studies[8].

Basically the spacing between the frequency components and the intensity will be the predominant factors.

THE EAR AS SPECTRUM ANALYSER

Experiments has shown that the ear/brain separates the audio spectrum into 24 bands called Barks. Up to 500Hz each Bark has a bandwidth of 100Hz and thereafter approximately 20% of the center frequency. Fig. 4 is a tabel of the defined Bark filter bands.

From the table it is noted that at low frequency the ear's resolution is very coarse.

TIME WEIGHTING OF THE LOUDNESS

When a sound is detected by the ear the percepted loudness will increase with time. Thus short peaks is not heard and first after a duration of 500 ms the `true´ loudness is recognized. The regulation time constant has been estimated to approximately 100ms by experiments. Fig. 5 is a graph showing the typical relationship between the percepted loudness vs. time.

THE ISO 532 - METHOD FOR CALCULATING LOUDNESS LEVEL

In order to cope with all the measurable parameters the ISO[1] issued a specification that descibes a system being able to determine the objective loudness level of noise signals in different environments. Two basic methods are described, but none of the methods are directly aimed towards the analysis of an audio signal. However, one of the methods (B) is more adequate for complex sound spectra or irregular spectra and is therefore considered to represent an audio signal. Fig. 6 shows the basic loudness calculating system.

SIGNAL FLOAT OF THE LOUDNESS CALCULATION

The audio signal is sourced to a real-time 31 band 1/3-octave spectrum analyser designed according to IEC 225[6]. At the output of the spectrum analyser the signals are detected and time-weighted. The detector and time-weighting circuitry is designed to be in accordance with IEC 651[7]. Both fast (125ms) and slow (1000ms) averaging time is implemented. Optionally the standard PPM[2] detector is selectable.

The time weighting signal is calibrated in decibels.

The 1/3-octave signals are then frequency weighted in respect to the hearing curves and combined into a single loudness figure according to the optimized method described by E. Zwicker[9]. The loudness value is thereafter displayed on the metering system.

IMPLEMENTATION IN THE METERING SYSTEM

The DK-AUDIO Master Stereo Display family take its origin in the all-in-one philosopy. Even complex functions such as required by the loudness indication must be reachable by the touch of a key.

Normally the meter is connected to the output of a audio console rather than a microphone.

Inside the unit we find a dual A/D-converter, very high speed Digital Signal Processor, operator key pad and display system.

The real-time loudness calculating system is extremely demanding. The average loading of the DSP-chip is more than 22 mill. operations per second and only state-of-the-art chips are able to provide that kind of through-put.

INTERPRETATION OF THE READING

As previously mentioned, the loudness indication refer to an absolute sound pressure level. The sound pressure is not measurable since it is at the front of the TV set at home, Hi-Fi set, car radio etc. Also the type of programme broadcasted and the target group are important parameters to know.

From the meters front panel the expected sound pressure at the listeners location can be entered.

In order to get an idea of the scaling of the sound pressure level one should think about the audio in movie theaters. Theatres equipped with surround sound reproduction facilities will all be aligned to provide a sound pressure of 85 dB in the center of theater.

Fig. 7 is a table of an old test conducted by the BBC[10]. The table should be interpreted having the time span in mind, and the average listening level today is supposedly higher. However, the trend shown in the table may very well still apply. In all cases it is up to the producer to estimate the listening level of the listener for each programme.

CONCLUSION

The loudness calculating meter is a `new´ approach to an old defined problem. The objective loudness value will enable audio engineers to mix to the correct absolute sound pressure level, and not to their individual preferences. Fixing the loudness level at the mixing-desk will not only please the listeners, but also improve the frequency balance of the end product.

It is also important to notice, that the system described is based on international standards, and not on proprietary developments. This fact makes it possible for independant suppliers to develop competitive products which in daily use will provide the same standardized indication.

REFERENCES

1) International Standard ISO 532, 1st edition - 1975-07-15

2) International Electrical Commision, IEC 268-10, 2nd edition - 1991-03

3) International Electrical Commision, IEC 268-17, 1st edition - 1990-09

4) Institut für Rundfunktechnik GmbH, Pflichtenhefte 3/6, 1st edition, Jan. 1997

5) Dansk Reklamefilm: "Audio Specifications for Cinema Screen Commercials".

6) International Electrical Commision, IEC 225, 2nd impression 1982

7) International Electrical Commision, IEC 651, 1st edition 1979

8) E. Zwicker, Institut für Elektroakustik der Technischen Universität München.

9) Programme zur automatischen Bestimmung der Lautheit aus Terzpegeln oder Frequenzgruppenpegeln, Acusta, Vol.27 1972 Heft 5

10) Listeners sound-level preferences, Sommerville, T and S.F. Brownless, BBC Quarterly 3.4 jan. 1949

Fig. 1 **PPM block diagram**

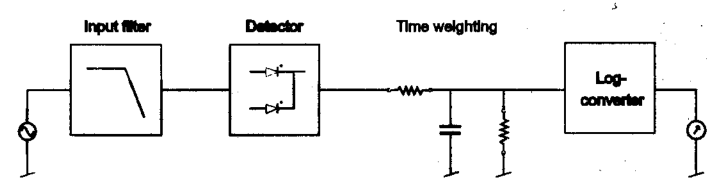


Fig. 2 **Level Record Layout**

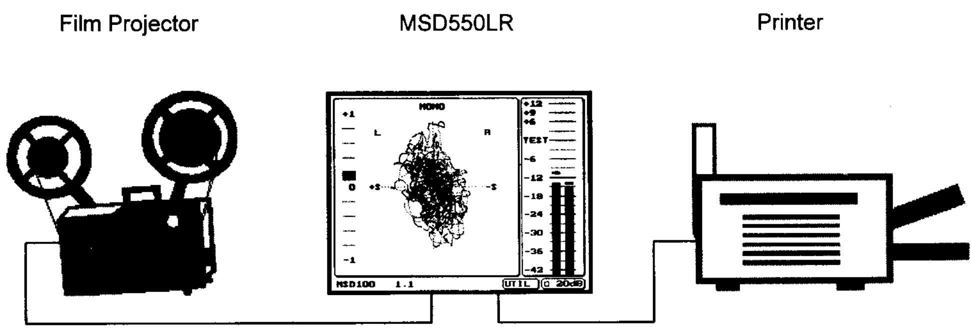
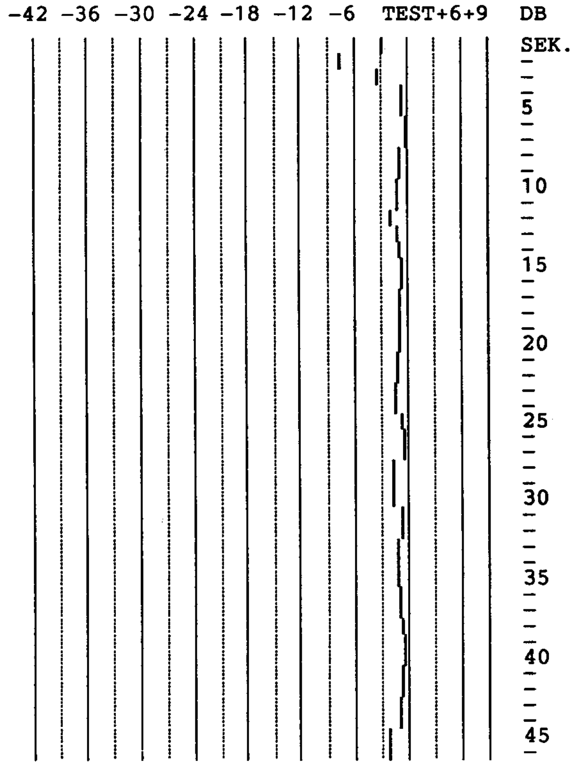


Fig. 3

KONTROLMÅLING AF STEREOLYDNIVEAU PÅ BIOGRAFREKLAMEFILM	
PRODUKT	Smirnoff
FILMTITEL	Cruise — A-KOPI/KOPIOPLAG
MODTAGET FRA	KS
DATO FOR MÅLING	22/8-91 KL. 16[11]



LYDNIVEAUET MÅ IKKE OVERSTIGE TESTMÆRKET

SIGN	MAX	GODKENDT

DANSK REKLAME FILM A/S DK-AUDIO, MSD550LR VER 3.2L

Dolby testfilm kørt kl. 13/08

Att. Hans Vermeij

"GODKENDT" means APPROVED "AFVIST" means REJECTED

Fig. 4 Table of the Bark Frequencies

BARK	F-low	F-high	F-center	BW
0	0	100	50	100
1	100	200	150	100
2	200	300	250	100
3	300	400	350	100
4	400	510	450	110
5	510	630	570	120
6	630	770	700	140
7	770	920	840	150
8	920	1080	1000	160
9	1080	1270	1170	190
10	1270	1480	1370	210
11	1480	1720	1600	240
12	1720	2000	1850	280
13	2000	2320	2150	320
14	2320	2700	2500	380
15	2700	3150	2900	450
16	3150	3700	3400	550
17	3700	4400	4000	700
18	4400	5300	4800	900
19	5300	6400	5800	1100
20	6400	7700	7000	1300
21	7700	9500	8500	1800
22	9500	12000	10500	2500
23	12000	15500	13500	3500

Fig. 5 **Time weightings**

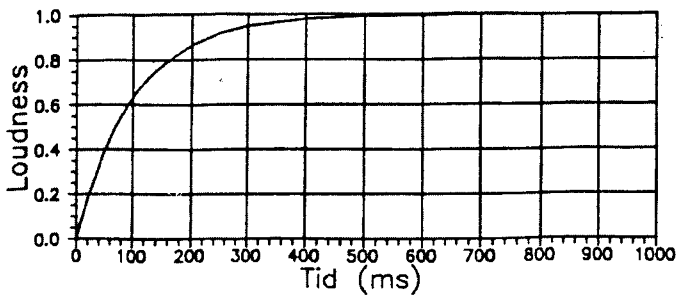


Fig. 6 **Block diagram of Loudness Meter**

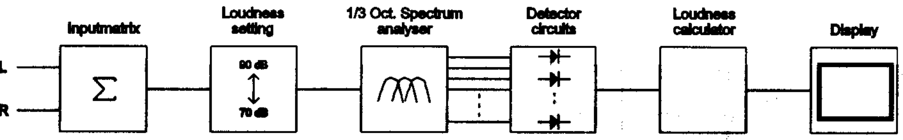


FIG. 7 **Preferred Listening Level**

	Public			Prog. Engineers		
	Men	Women	Musicians	Men	Women	Engineers
Symphonic music	78	78	88	90	87	88
Light music	75	74	79	89	84	84
Dance music	75	73	79	89	83	84
Speech	71	71	74	84	77	80

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