"How do we ensure that a Test System provides the correct results?"
Or
"Calibration is no substitute for poor equipment design or build quality"

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Overview

Whenever a new format is launched, calibration is always flagged up as being of great importance. Calibration is often considered the "cure-all" for ensuring that all test results, from all test systems, on a given disc, are similar (for the purpose of this discussion 'similar' is generally considered to be within 10%).

Unfortunately, this is not the case. Calibration alone will not ensure that all measurements from all test systems on a given disc are similar.

Actually, what is of great importance at the start of any new format is a Reference Standard (not a calibration standard). We describe below how correct equipment design, a high level of product quality, and a correct (limited) amount of calibration combined with a Reference Standard, can ensure that all discs tested on DaTARIUS equipment give the correct results.

Key Elements of an Electrical Test System

Below is the "Holy Trinity" of objectives that we aim to achieve with every test system developed.

- **Accuracy to a Reference Standard** – When developing the test system it is important that the measurement results closely match the Reference Standard.

- **Repeatability –** It is essential that repeated measurements on the same test system, using the same disc, produce very similar results (provided the disc remains the same). Without repeatability, the test system is broadly useless, because the user has no idea what the accuracy is for a given measurement: for instance, a broken clock can be highly accurate twice per day.

- **Reproducibility-** It is essential for a production environment that the measurement results from test system A on disc A provide very similar results to test system B on disc A, otherwise the user is left to toss a coin regarding which is correct. Reproducibility is often the last of the Trinity to be spoken about. This is primarily because it is the hardest objective to achieve for the test equipment manufacturer as it requires a lot of consideration at the beginning of the design and is very difficult to engineer into a product at a later date. It is also costly from the point of view of building test equipment. However, it is an important issue for all but the smallest disc manufacturers, who may have only one test system.

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What is a Reference Standard in Optical Media? Is it a Disc or is it a Test System?

In reality, both are used to create a Reference Standard, because the electrical parameters of a disc are a function of the disc and the readout system (the drive), which is why we place so much emphasis on a reference drive design.

Initially, a disc or small family of discs are created that are aimed to display a range of disc quality: signals that are too low, just right, and too high. This disc is then tested on test systems defined as reference systems (often by the format developers or the format standards body, such as the DVD Forum). The collective results are then used to create a reference set of results for the discs; this set then allows owners of the reference test equipment to understand the deviances between the reference test equipment. This is known as round robin testing. Figure 1 shows a round robin test, which we carried out on a variety of different test systems, from a variety of different manufacturers; the aim was to establish a reference value for PRSNR on this disc.

ABEX 940 L1 PRSNR
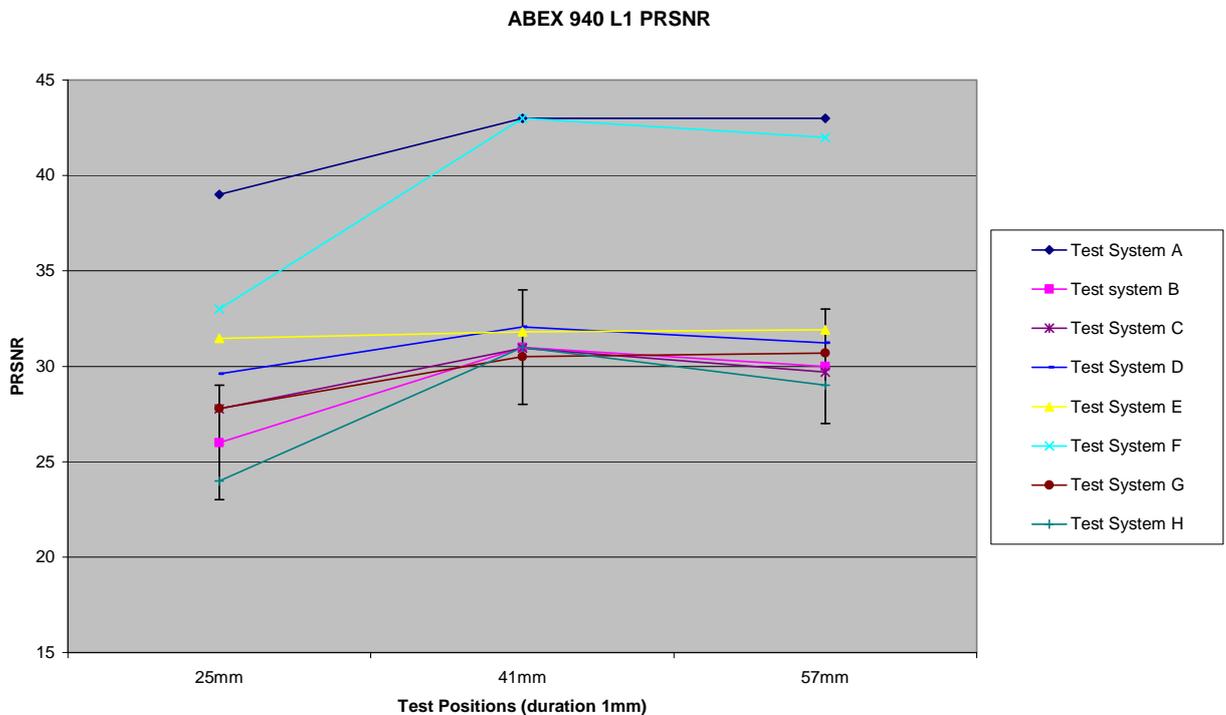
Figure 1: PRSNR round robin test

On DVD, selected sites were established, who were approved to provide reference standard measurements on discs – these were called A Labs (a similar process is occurring for HDDVD and BD).

In addition, Philips supported the distribution of a reference disc set for DVD, with the option of having each disc individually measured and characterized under A lab conditions.

Figure 2: Philips single and dual layer reference discs

However, the realization of a Reference Standard for optical media is flawed in that it has a finite scope, mainly due to time and cost – because it is one or a limited set of discs, it can ultimately only represent a small range of the features that can effect signals on a disc.

How do We Ensure Correct Results (Accuracy, Repeatability and Reproducibility, or AR&R?)

- Design – it is not enough to consider AR&R after the design and development of a test system is finished. We separate test system design into three main areas:
    - User Software
    - Electronics and Signal Processing
    - Drive – the drive is further subdivided into
        - OPU (our reference standard OPU is shown in Figure 2)
        - Drive Mechanics
        - Drive Electronics

Figure 3: OPU

Our first goal is to design the entire system in agreement with the physical specifications defined for the media and therein requirements for a Reference Test drive.

- Build Quality – It is essential that our design has built in quality, and that we are able to make the first system very similar to the last. For this reason, we have in-house control over every major element of our test system from the design and development of the OPU, the build of the drive, the design of the signal analysis software, GUI etc.

- Limited Calibration – Calibration to ensure a test system matches the Reference Standard implies that the test system is not the same as those used to define the Reference Standard; therefore, it already casts into doubt if the results will be correct. We do not believe in general calibration, more we believe that the test system should match the Reference Standard because it is built in accordance with the Reference Standard. However, in a few limited areas it is not always possible to ensure that the test system is always the same – the main area is related to unnormalized signals such as reflectivity. Small amplification differences within the electronics chain can result in slightly different values, therefore in this area we apply a simply calibration which is traceable to a reflectivity standard.

This is a very top level treatment of the design of a test system, enough to get the flavour of what is required. A much more detailed description of how to ensure AR&R is given in another article entitled "Demystifying the drive" download @ http://www.datarius.com/news/white_paper-PDF/wp_demystifying_the_drive.pdf

Common Problems with Using Calibration as a "Cure-all" for Poor Test System Accuracy

If the reference disc is used as a "cure-all" to calibrate all signals, then the reference disc becomes a calibration disc and we run the risk of having the problems described below.

- Poor overall accuracy – The test system, if calibrated with the reference disc, may match the results on the Reference Disc but not on the full gamut of production discs. As earlier stated, due to cost and time constraints the Reference Standard is usually formed from a limited set of discs. Therefore, it is possible to "calibrate" a test system such that it is very accurate on this disc (provided the system is

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repeatable). However, this does not ensure that the test system will produce accurate measurement results on a wide range of discs.

- Poor Reproducibility – If the Test systems are not built with a high degree of consistency the calibration ensures good reproducibility – FALSE. It will only ensure good reproducibility on the disc used for calibration; it is most likely to make the general reproducibility of the system far worse.

NB: a very good test of the design and build quality of a test system is to study the level of repeatability, because this member of the "Holy Trinity" is unaffected by calibration. If a test system shows good results on a good quality reference disc, then try looking at the repeatability on a disc close to the limit. If this repeatability is poor it is a very good indicator that accuracy and reproducibility will be poor, and that a "cure-all" calibration approach has been used, rather than good system design.

Conclusions

Our view of how to ensure correct results from a test can be summarized as follows, along with some pointers on how to determine a good test system:

- Calibration is No Substitute for Good Test system Design and Build Quality

- When determining the quality of a test system, always look closely at the accuracy to reference media with "uncalibrated data"

- Calibration applied incorrectly will make reproducibility, and hence accuracy, worse.

- Study the repeatability of the test system, this can not easily be made good using calibration, and poor repeatability will mean accuracy and reproducibility are not good enough – even though they may look ok on a reference disc.

This discussion in this article is aimed at our core competence of electrical test systems, however, much of the content could be equally applied to other types of test systems.

About DaTARIUS Technologies GmbH

The DaTARIUS Group is a global company focused on providing solutions throughout the optical media manufacturing industries. DaTARIUS developed the first commercial CD test system and has over 20 years' experience in the manufacture and distribution of equipment for inspecting, measuring and optimizing at every stage of the optical media manufacturing process.

DaTARIUS is unique in providing equipment for the entire production process right through from pre-mastering to print and packaging. Its products are suitable for every optical media format – pre-recorded and recordable – from CD & DVD through to the new blue laser BD and HD DVD formats, and other emerging formats such as HD VMD.

In addition, DaTARIUS also develops and supplies process optimization equipment, such as sprue recycling and mould temperature regulations systems. This broad product range is supplemented by consulting and training services.

Beyond optical media, DaTARIUS, in partnership with InPhase, is developing quality control equipment for the next generation of holographic formats.

With headquarters in Reutte, Austria (R&D, sales and service), and regional offices in America Germany, Japan, China and Hong Kong, the DaTARIUS Group has a global team of 100-plus employees and partners with an extensive sales and service support network covering every major market of the globe: North America, South America, Europe, the Middle East, and the Pacific Rim.

For more information on the company and its products, visit www.DaTARIUS.com

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