New Approach of Loudspeaker Data Presentation in EASE4.2

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Introduction

Since simulation software for sound systems is available, the loudspeaker industry is providing speaker data to be used in such programs. These data are based on magnitude-only numbers and mainly kept in tables. This way in EASE the so-called SPK format has been developed over years, describing typical point source behaviour. But nowadays diverse speaker arrangements are available which are impossible to describe as simple point sources.
For example, there are a lot of line array systems available. Furthermore, the capabilities of DSP processing and digital control over loudspeakers have led to another branch of sophisticated sound systems, namely the steered loudspeaker columns. Additionally the technology of so-called loudspeaker clusters has evolved, too. The accurate design, arrangement and alignment of an assembly of loudspeakers have provided answers to many questions arising in the context of installing multi-purpose sound systems.
Based on these perceptions and on many years of experience in the creation of acoustic simulations and measurement our group introduced a new data format that is designed to appropriately describe sound systems with complex mechanical, acoustic and electronic properties. The data format, called Generic Loudspeaker Library (GLL), is designed to provide a more systematic way to analyze, model and compare advanced loudspeaker systems in acoustic prediction software, but also to provide a standardized interface for storing and exchanging the underlying acoustic data in a reduced or high resolution /1/,/2/, /3/,/4/.

1 Concept to create and use a GLL

The GLL format is generally designed to describe loudspeaker systems and acoustic sources of any kind, see Figure 1. This particularly includes

- conventional line arrays,
- column loudspeakers and steered columns,
- loudspeaker clusters and arrays,
- multi-way loudspeakers.

The GLL is intended to become a general exchange format to describe loudspeaker systems, for example for use in EASE software applications /3/.

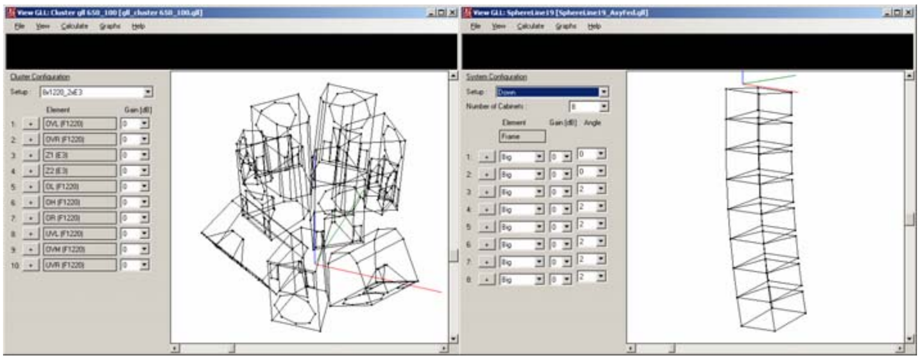


Figure 1: GLL Loudspeaker Cluster or Line Array as appearing in the EASE GLL Viewer

The design of the GLL tries to generically address the following problems that became apparent in the past when using conventional balloon directivity data for describing loudspeakers:

- modeling and use of line arrays with variable rigging setups and angular configurations,
- modeling of column loudspeakers, digitally controlled or conventional,
- modeling of cluster loudspeaker systems with different predefined setups,
- modeling of multi-way loudspeakers, in particular when combining them,
- definition of power handling for a multi-way loudspeaker,
- use and configuration of external crossovers,
- modeling of internal crossovers and of equalizers,
- definition and application of complex balloon data,
- definition and application of angular and frequency resolution of acoustic data.

Although some of these problems will not be solved entirely, the new Generic Loudspeaker Library will significantly improve the accuracy of existing approaches.

A major simplification that typically has been made was the reduction of multiple acoustic elements, such as drivers, of a loudspeaker to an abstract single element. This could also be understood as reducing a complex loudspeaker box to a single acoustic source. A natural way to overcome the limitations connected with that approach is to treat an acoustic source actually like an acoustic source and a loudspeaker box like a loudspeaker box. This concept not only inherently increases the accuracy of the model but also eliminates the problematic questions related to the reduction of data.

Technically the GLL is a data file. It is created by the manufacturer from a so-called GLL project through a step called compilation. The compiled GLL contains all of the data related to the particular loudspeaker system. It is then able to be configured by the end user in the prediction software. The allowed configuration possibilities are defined previously by the manufacturer in the GLL project. As an example, this may include internal crossovers, possible box splay angles or cluster configurations. The user may then select specific filters or the splay angle between two boxes in this case in the prediction software.

In the following we use loudspeaker arrangements to show the good agreement between measured speaker data and simulated ones used in EASE4.2 SpeakerLab based on the GLL approach /2/.

1.1 Two-Way System

First we consider a two-way loudspeaker in general. We model the full-range response of a real-world system based on the measurement data for the high-frequency unit (HF, Horn) and the low-frequency unit (LF, Woofer) respectively and compare the calculation results with the measurement data for the full-range setup (FR) where both transducers are driven simultaneously.
In particular we discuss the use of measurement data acquired using the HF center and LF center individually as the point of rotation (POR) in contrast to using the centre of gravity of the speaker as the common point of rotation for both HF and LF. We evaluate the significance of complex data by comparing predictions based on magnitude-only data with calculation results based on magnitude and phase.

The loudspeaker model used for this analysis is a PNX121T from Renkus-Heinz. Figure 2 shows a drawing that outlines the locations of the Horn, the Woofer and the Port.
We note that the crossover region is located around 1.6kHz with a width of about 1/3rd octave. This will be our main area of concern; below and above this frequency bandwidth the full-range system can be represented by either only the LF or the HF unit.

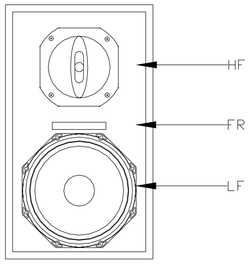


Figure 2 Drawing of PNX121T with indications for Horn (HF), Port (FR) and Woofer (LF)

Measurement vs. Prediction

Here we will compare two different setups with the measured full-range data:
Complex HF and LF data and magnitude-only HF and LF data measured at the respective centers
Complex HF and LF data and magnitude-only HF and LF data measured at the gravity centre of the loudspeaker box
The measured full-range data was acquired by rotating about the gravity centre.

Use of Individual Centres

At first we compare the simulation results with measured data based on the Horn being rotated about its centre and the Woofer being rotated about its centre during the measurement.

Figure 3 shows the vertical polars of this configuration. All three data sets, simulation using complex data, simulation using magnitude-only data and the measurement show good agreement. Naturally deviations are greater for the backside of the loudspeaker.

For the shown 1/3rd octave bandwidth, where statistical errors are smaller, the radiation from the rear of the loudspeaker is slightly overestimated by the simulation using magnitude-only data. This may be an indicator for the fact that the phase data is almost random (incoherent) at the back and thus leads effectively to an energy summation of HF and LF in the complex model, while the magnitude-only model assumes a degree of coherency that is not present.

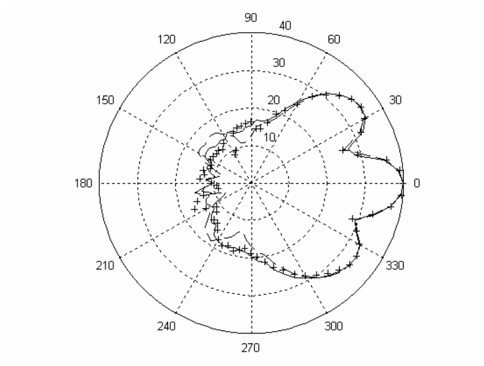


Figure 3 Comparison of prediction using complex data (-), magnitude-only data (--) and measurement (+), based on individual centers for 1600Hz at 1/3rd octave bandwidth

Use of a Common Point of Rotation

Next we compare prediction results based on HF and LF measurement data that was acquired by rotating about the gravity centre of the loudspeaker. The reference for comparison is the same full-range measurement as before.

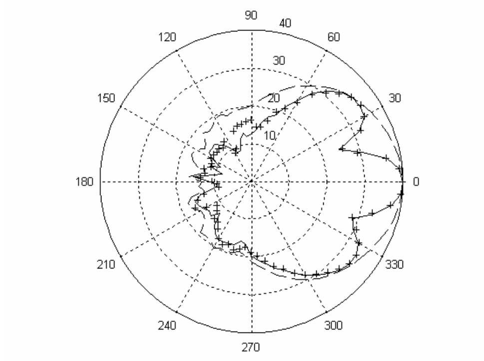


Figure 4 Comparison of prediction using complex data (-), magnitude-only data (--) and measurement (+), based on rotation points located at the port for 1600Hz at 1/3rd octave bandwidth

Figures 4 shows the vertical polars of this configuration. It is obvious that calculations using the complex model correlate very well with the measurement, but the calculation based on the magnitude-only data does not agree at all.

This can be explained by the fact, that now the spatial arrangement is entirely stored in the phase data. The phase data includes the run time phase differentials due to the offset between HF centre and port (or LF centre and port) for every point on the balloon surface. By omitting this information, the HF and LF practically become re-located directly at the gravity centre.

Individual Centres vs. Common POR

Finally we want to directly compare the two complex models, one based on individual centers and the other one based on rotating about the gravity centre.

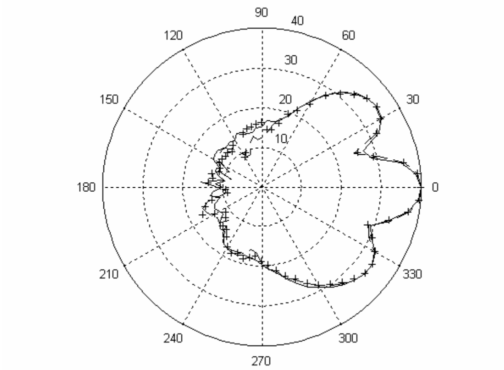


Figure 5 Comparison of prediction using data for individual centers (-), using data based on rotation points located at the port (--), and measurement (+), complex model for 1600Hz at 1/3rd octave bandwidth

Figures 5 shows a very good agreement of the vertical polars calculated and measured.

From the above we can conclude that both complex models, either based on measuring about the centers of the HF and LF unit or based on measuring about the common gravity centre of the box, provide equivalent answers that match the measurement data well. However, if magnitude-only data is to be used for calculation purposes the physical offset between the point of rotation and the center of the source has to be minimized (For crossover systems with multiple sources this is often not even possible.). Otherwise the lack of phase data will lead to erroneous results /4/. This finding has practical relevance, as re-mounting a device when running a series of measurements can require significant time. It may also introduce additional errors due to changed geometrical conditions.

1.2 Cluster System

In the previous section we have considered a single two-way loudspeaker. After that, the consequent next step seems to be evaluating a more complex setup that involves more sources and spatial variations.

In the following we will consider a cluster setup of 2 two-way loudspeaker systems. We will be using the PNX121T, which is already well-known with regard to the high-frequency, low-frequency and full-range data. Predictions for three different configurations are compared with measurements:
Vertical stack with the horns located close to each other (HF-HF)
Vertical stack with the woofers located close to each other (LF-LF)
Side-by-side arrangement

We will focus in particular on predictions utilizing either two full-range data sets, one for each box, or data for the four involved drivers. Comparisons of both complex model and magnitude-only model with the measured data will be performed.

When including data for the HF and LF individually we refer to the measurements about the respective centers, to maintain comparability between magnitude-only and complex model.

Stacked System, HF - HF

The setup for the horn-to-horn measurement and simulation is shown in Figure 6. Based on this configuration we will first present the results of calculations using the full-range response of the two boxes. After that we will compare these findings with the simulation results using the data of the four transducers individually.

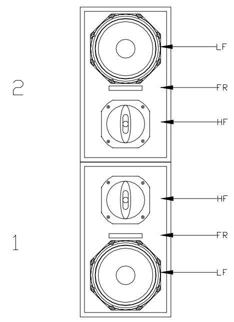


Figure 6 Drawing of “HF-HF” setup

Simulation with 2 Full - Range Systems

The directivity balloon for the setup shown in Figure 7 was calculated based on two point sources, one representing loudspeaker 1 and the other one loudspeaker 2. The full-range measurement data used for each point source was the same, but the balloon data used for loudspeaker 2 was rotated by 180°. The locations of both point sources were set to the respective ports.

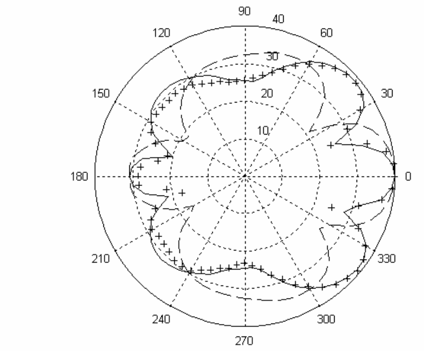


Figure 7 Comparison of prediction using complex data (-), magnitude-only data (--) and measurement (+), based on two full-range sources, calculated for 500Hz at 1/3rd octave bandwidth

Figures 7 show the vertical polars that result from applying the complex model including phase data and from applying the magnitude-only model. Additionally the polars are displayed as measured for the whole ensemble.

We note that the complex model closely tracks the measurement data. Except for some differences at angles near a main lobe, the agreement is very good. In contrast, the magnitude-only model seems to produce fairly different results, both quantitatively and qualitatively. Looking back at the simple two-way comparisons above this seems logical, as again phase data is needed to properly describe the spatial arrangement of the Horn and the Woofer inside each cabinet.

Simulation with all the 4 Sources inside the two speakers

A similar calculation was performed for the same setup, but this time including the individual sources, namely HF and LF of loudspeaker 1 and HF and LF of loudspeaker 2. In the prediction each of the four is represented by a point source, located at the respective center (Figure 6). For the two HF units, and for the two LF units respectively, the same data was used, but the directivity balloons for the horn and the woofer of loudspeaker 2 were rotated by 180°.The results for the vertical polars are shown in Figure 8 for 500Hz.

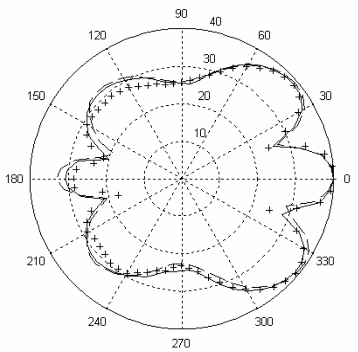


Figure 8 Comparison of prediction using 2 full-range sources (-), using 4 sources (HF or LF) (--) and measurement (+), based on complex model, calculated for 500Hz at 1/3rd octave bandwidth

In most cases the measured data seems to be slightly different with respect to the shape and extent of maxima and minima, especially maxima are broadened and minima seem not as deep as in the prediction. This can be explained by the fact that in the real-world there is always a small amount of random averaging involved that is for example due to moving air, diffraction effects and the finite size of the microphone. Therefore extreme values appear slightly smoothed in the measurement compared to the prediction.

Stacked System, LF - LF

By using in contrast to the setup of Figure 6 (horn-to-horn) a woofer-woofer setup, we obtain of course the same results by using magnitude-only data. As already expected, simulation results utilizing 2 full-range sources in the magnitude-only model do not match the measurements very well. Like for the HF-HF setup there is no information about the spatial relationship between HF and LF stored in the data.

The curves derived using the complex model show generally good agreement with the measurement data. These effects are greater for lower frequencies and therefore may indicate some low-frequency interaction between the adjoined woofers, see Figure 9 in comparison to Figure 7.
We note that the difference between the magnitude-only predictions for HF-HF on one hand and LF-LF on the other hand is mainly caused by the small change in distance between the gravity centres and thus the point sources. This was verified in the simulation.

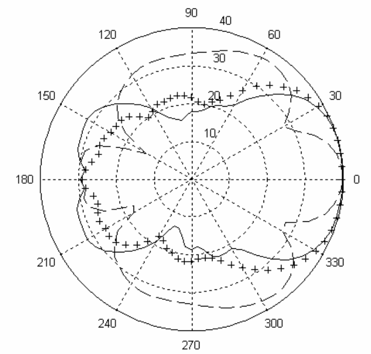
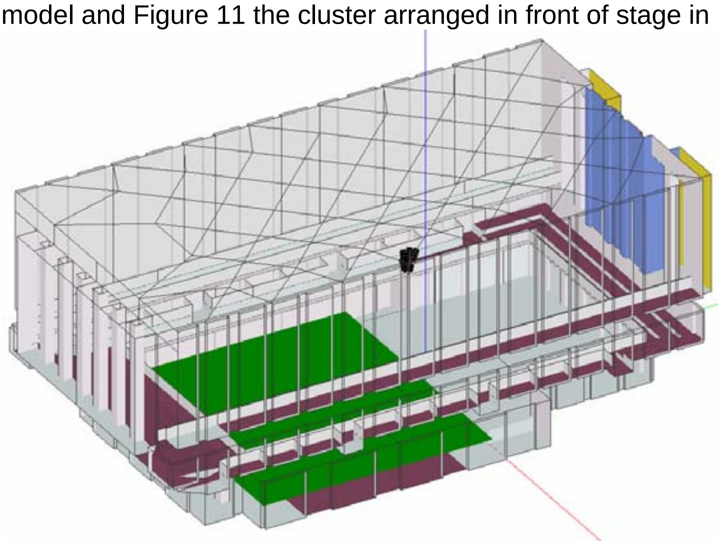


Figure 9 Comparison of prediction using complex data (-), magnitude-only data (--) and measurement (+), based on two full-range sources, calculated for 500Hz at 1/3rd octave bandwidth

2 Model and GLL

In EASE 4.2 /5/ we modelled a concert hall in Berlin and used a cluster of 10 speakers to compare the simulation results for different calculation routines. The next figure 10 shows the computer model and Figure 11 the cluster arranged in front of stage in a height of 9.5 m over stage level.



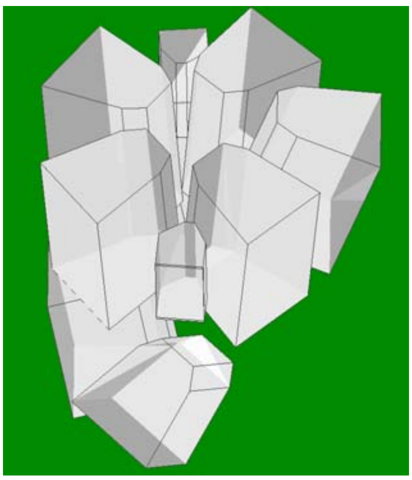


Figure 10: Model of the hall with the cluster in EASE4.2

Figure 11 View of the used Cluster

The different calculation routines have been executed on the listener areas in the ground floor of the hall shown in green in Fig. 10, any used measurement points MP1 to MP4 later used for comparisons with the simulation data are placed on these two listener areas.

2.1 Comparison between simulations with GLL and Point source approach

In EASE 4.2 /5/ we have several possibilities to calculate the sound pressure levels on listener areas produced by loudspeaker arrangements. One method is to use all speakers in a cluster as individual systems and to overlay their SPL contributions by summing up the levels with and without phase consideration (with and without phase). Already in EASE 3.0 a far-field cluster calculation was introduced. The result is a new point source and phase influences are only considered in the far field. The new GLL approach is the only method using all single speakers in the real behaviour, considering the interactive phase relationship and is also valid in the near field. The next Figure 12 shows Direct sound level comparisons at the mentioned listener areas.

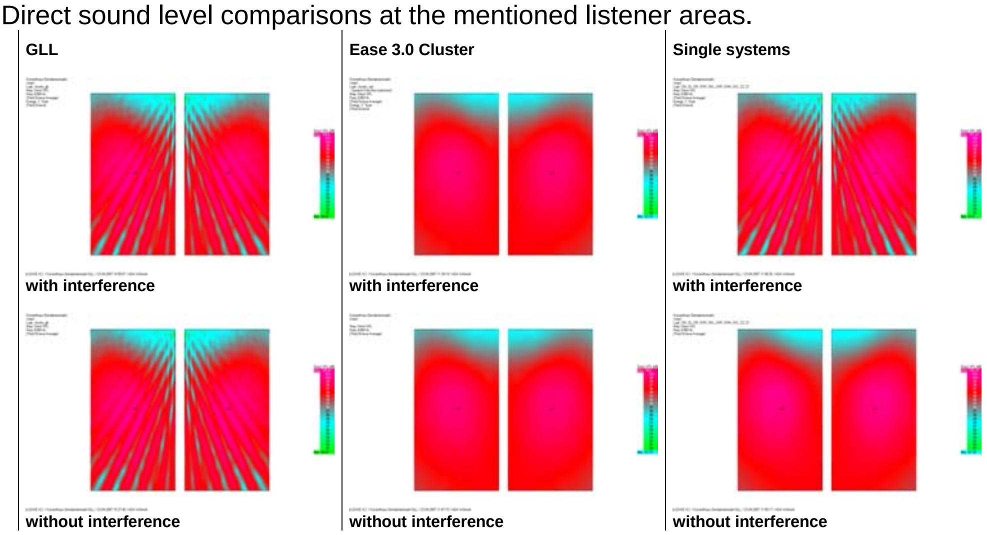
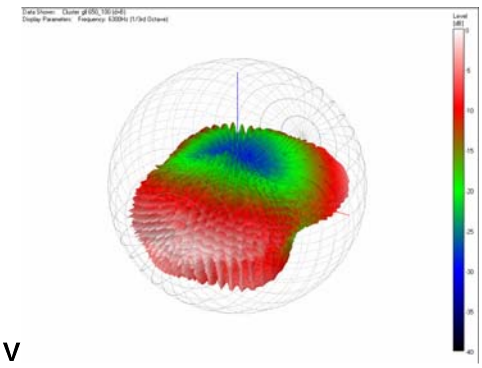


Figure 12: Direct SPL comparisons for 6300Hz

By evaluating the three figures it becomes obvious that in case of GLL calculations any phase relationships between the components of the cluster will be considered by the GLL internally, so no differences are visible between the post-processing routines with or without interference. The same is valid by applying the EASE 3.0 cluster routine with the principal difference that the phase relations are considered only for the far field and the resulting point source is based on a 5º-calculation grid, which causes inaccurate level patterns at higher frequencies.
For the shown 1000Hz the results deviate from the right ones done with the GLL calculations. This becomes very obvious in fig. 13, where the balloons for 6300Hz are compared between the GLL calculation (here 2.5°) and the EASE 3.0 cluster method (here 5°). Because of the used 5º grid all fine ripples of the balloon are disappeared in case of the classical cluster calculation, which leads to the different results in fig. 12. By using the interference method for all single components of the array we obtain the same results as with the GLL, without interference (simple power summation) we get smooth, but more or less wrong results.



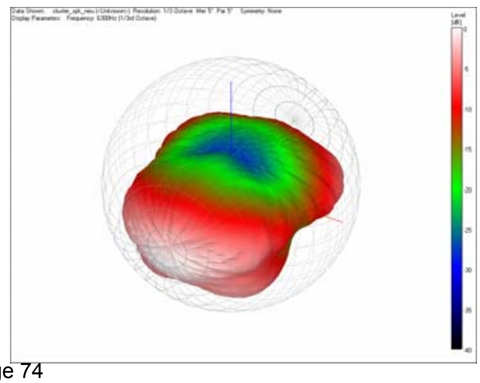


Figure 13: Balloon comparison GLL and EASE3.0 cluster calculation for 6300Hz

As a result of all of these and other comparisons (see also Figure 14) the superiority of a GLL approach to predict the acoustic behaviour of sound radiation is shown. This already became visible based on the GLL used here, which was constructed of 10 individual loudspeakers each measured as a full-range point source. A more precise way to come closer to even more realistic values would be an improved GLL model for every single speaker, which would be based on two point sources for each box including filters (a horn and a woofer connected via a crossover). The resulting model would now consist of these three elements and by measuring the acoustic properties of these sub point sources we should have at least an overall GLL consisting of 10x2 point sources connected via a complex filter network. Such an approach should lead to even more realistic prediction results. Meanwhile we verify how our actual GLL approach with the 10-point sources looks in comparisons with actual measurements done with EASERA /6/.

2.2 Comparisons between simulation methods and Measurements

In Figure 14 for two different measurement places at the listener area according Figure 10 a comparison of the Direct SPL is shown between simulation and measurement. As visible we obtain a good agreement between the results. At the low end the measurements show also lower values. This is caused by the window technology we applied to derive the direct sound from the overall measurements.

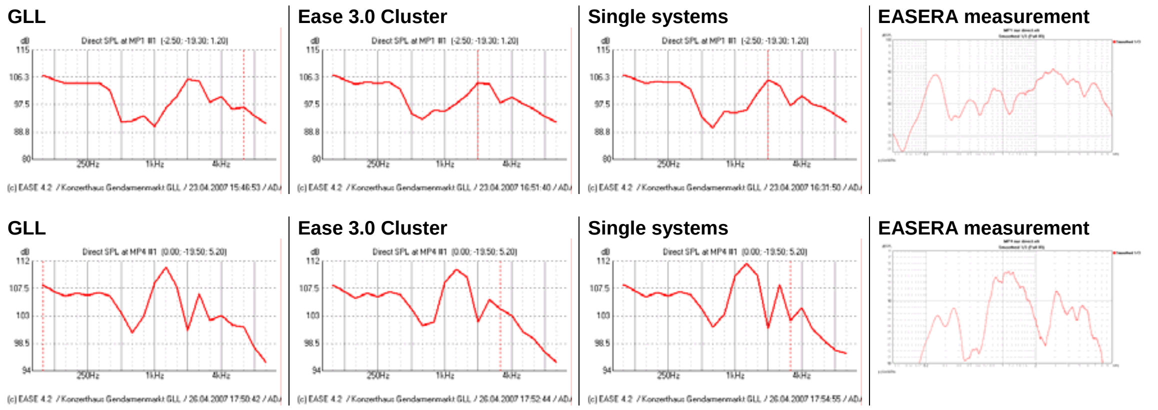


Figure 14: Comparison between simulation and measurement for two measuring locations MP1 and MP2

A new tool has been developed to allow frequency-dependent filtering of live and post-processed data. The next Figure 15 shows this kind of pink-filtering in EASERA SysTune /7/ for results of MP1 (upper line in Figure 14).

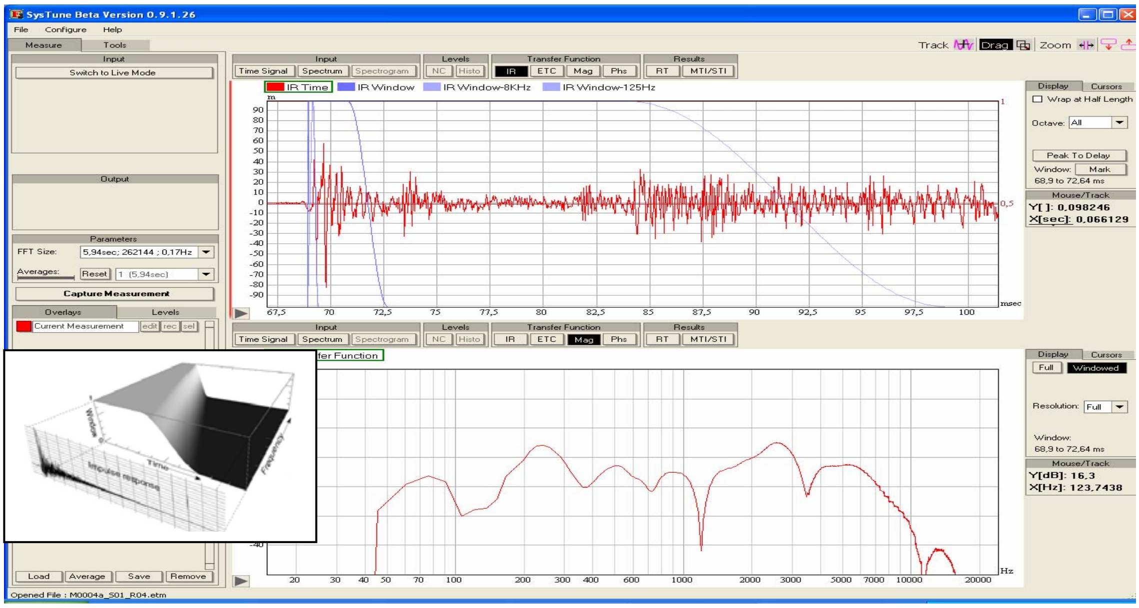


Figure 15: TFC or Pink-Filtering of measurement results at MP1

This tool EASERA SysTune is able to process 8 channels live signals at the same time, even with music or speech excitation. So any GLL calculations in SpeakerLab and simulation with it in EASE may be verified in practice in a simple way. The next Figure 16 shows a measurement setup (here for demonstration purposes the tool EASE Focus /8/ is used) with 8 microphones. So a fast averaging of the frequency responses may be done.

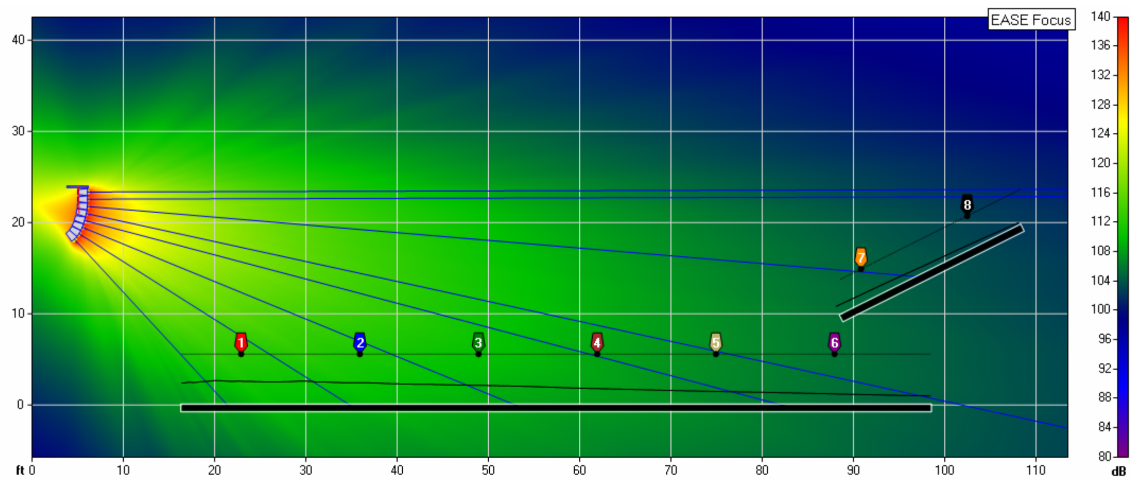


Figure 16: Measurement setup to tune line arrays with EASERA SysTune

Finally it should be mentioned that by using the GLL approach based on SpeakerLab processing the long expected interaction between software and hardware control becomes reality, see last Figure 17.

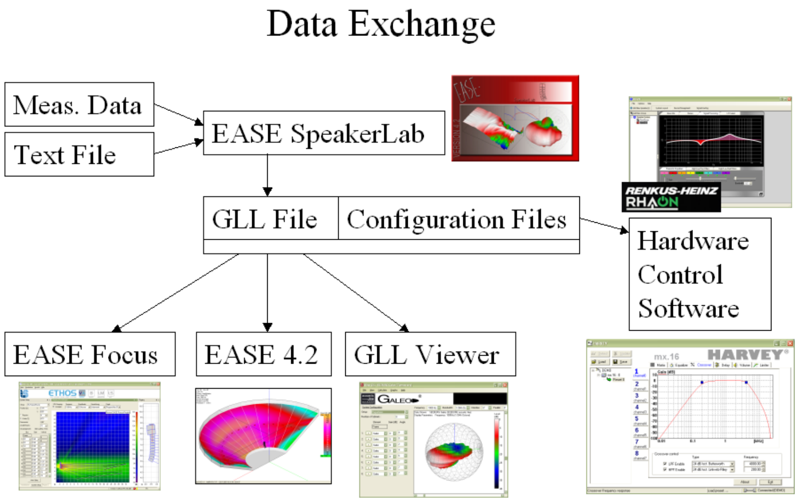


Figure 17: Data Exchange between Software and Hardware components

3. Conclusions

The creation of a so-called Generic Loudspeaker Library GLL for use in SpeakerLab and in EASE has opened a new door to predict the acoustic radiation behaviour of single or complex speaker arrangements like clusters or line arrays very precisely. It could be shown that by neglecting the phase interaction only rough results especially usable in the low frequency range can be obtained. So the authors are sure that simulation results based on magnitude values of polar data entered from any tables supply only orientation values and must be substituted by complex data. Here the manufacturers are forced to measure their devices with higher efforts. In this respect the new AES standard X-83 (in preparation) will provide the right guidelines how to measure polar balloons. Anyway, any modern computer-based measurement procedure will supply impulse response or transfer function data. So, at least for a well-calibrated measurement setup, it does not make sense to measure the complex data and to waste the phase information. By the use of complex data in prediction programs the accuracy of the results will be enhanced significantly.
By using such tools like modern measurement technique and exchange data formats the interaction between firmware and simulation software results becomes possible.

References:

1. S. Feistel, W. Ahnert and S. Bock: “New Data Format to Describe Complex Sound Sources”, pres. at the AES 119th Convention – New York, (2005 October 7-10); S. Feistel, W. Ahnert: “The Significance of Phase Data for the Acoustic Prediction of Combinations of Sound Sources”, pres. at the AES 119th Convention – New York, (2005 October 7-10)
2. S. Feistel, W. Ahnert: “Modelling of Loudspeaker Systems using High-Resolution Data”, pres. at the AES 121st Convention – San Francisco, (2006 October 5-8); revised 2007 May 16, *J. Audio Eng. Soc.*, Vol. 55, No. 7/8, 2007 July/August
3. S. Feistel, W. Ahnert, Ch. Hughes, B. C. Olson: “Simulating the Directivity Behaviour of Loudspeakers with Crossover Filters”, pres. at the AES 123st Convention – New York, (2007 October 5-8)
4. S. Feistel, W. Ahnert, T. Maier: „New Approach of Speaker Simulation for Sound Reinforcement”, pres. at the 19th International Congress on Acoustics– Madrid, (2007 September 2-7)
5. EASE Software, ADA Acoustic Design Ahnert, Berlin, Germany, http://www.afmg.eu
6. EASERA Software, SDA Software Design Ahnert GmbH, Berlin, Germany, http://www.afmg.eu
7. S. Feistel, W. Ahnert, A. Miron, E. Finder, “Experiences with a new Live Sound Measurement Tool”, pres. at International Symposium on Room Acoustics, Seville, 10-12 September 2007
8. EASE Focus Software, SDA Software Design Ahnert GmbH, Berlin, Germany