Shrink Your Lab, Not Your Results

Andrew Taylor
KLIPPEL GmbH, Mendelssohnallee 30, 01309 Dresden, Germany

1 Introduction

Speaker testing, from individual components to transducers to complete active audio systems, usually requires a lot of different equipment, which can lead to an expansive and expensive measurement setup. One way to downsize your R&D laboratory without compromising your measurement capabilities or accuracy is to use the unified solution offered by the Multi-Scanning Workbench from KLIPPEL GmbH. This modest setup works in a normal work or home office, dispensing with the need for a large baffle and anechoic room. With work from home (WFH) seemingly here to stay to some extent even after the COVID threat is sufficiently reduced, this becomes even more helpful. Results of an example transducer measured with this all-in-one setup are used throughout this article to illustrate the capabilities of the Multi-Scanning Workbench and the advantages compared to traditional testing methods.

2 Multi-Domain Measurements

Fully characterizing and evaluating speakers throughout the entire design phase requires measuring across many different domains. It is important to measure different signals in parallel because the effects and the root cause of a specific phenomenon often lie in separate domains. Being able to trace symptoms across domains is necessary for a deep understanding of the loudspeaker behavior.

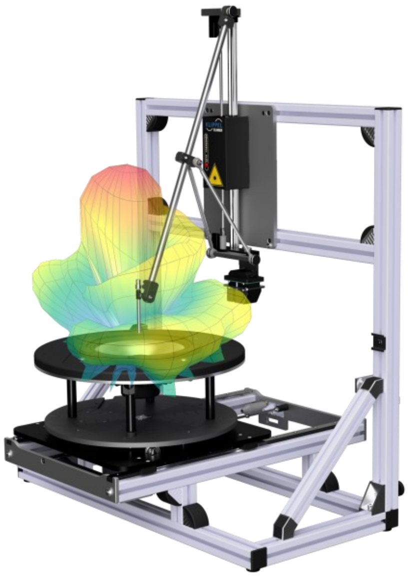

Photo 1: The Multi-Scanning Workbench from KLIPPEL GmbH.

3 Test Setup

Performing multi-domain measurements places a large set of needs on the measurement equipment and setup used. While there are plenty of high-end consumer and professional audio analysis tools available today, these solutions usually only combine electrical and acoustical testing. When using these options, sound radiation measurements conforming to international standards are typically performed using a baffle in an anechoic room. However, the accuracy of low frequency measurements is highly dependent on the sizes of the room, transducer and baffle and on the effectiveness of the low frequency absorption. Another problem is baffle vibrations. To combat this, baffles can be made from solid steel or concrete, but the increased weight can lead to handling problems.

The all-in-one Multi-Scanning Workbench equipped with the SCN Near Field Add-On, as seen in Photo 1, is a complete but compact solution. This hardware facilitates electrical, acoustical, mechanical, and magnetic testing. Measuring in these domains in parallel or switching between them is smooth and uncomplicated. The newly released acoustical scanning ability utilizes the same direct sound separation technique used in the Near Field Scanner (NFS), which also supports larger audio devices [1]. This technology has several advantages compared to normal far-field measurements, such as obtaining the full 3D sound radiation data in both the near and far fields in a shorter amount of time than could be accomplished with turntables and minimal microphone arrays. On top of that, a large baffle and an anechoic room are no longer needed. A small round baffle is sufficient because the signal processing can remove the influence of diffraction at the edges, acoustic shortcut and room reflections. By removing the traditional restricting factors of room and baffle size, this technology can be very accurate at low frequencies even when placed in a normal work or home office. This solution is perfect for comprehensive speaker analysis because it integrates everything that is needed into a space- and cost-efficient unified hardware that can quickly perform multi-domain measurements.

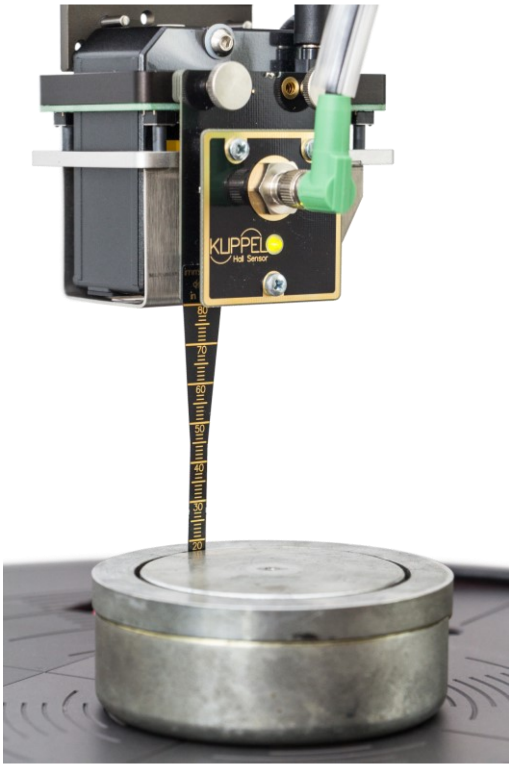

Photo 2: The BFS Sensor of the B-Field Scanner.

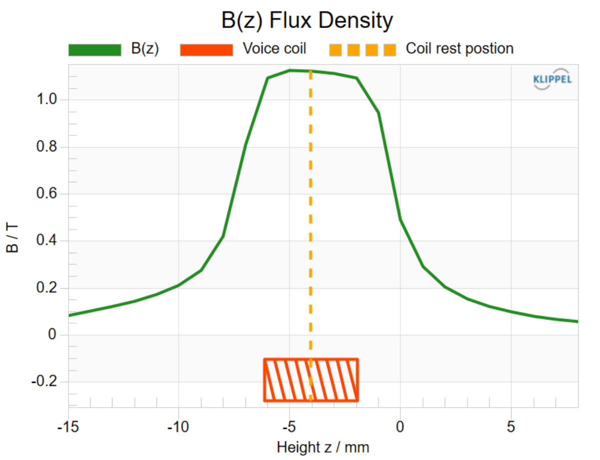

Figure 1: Flux density of the magnetic field of the magnet used in the example transducer.

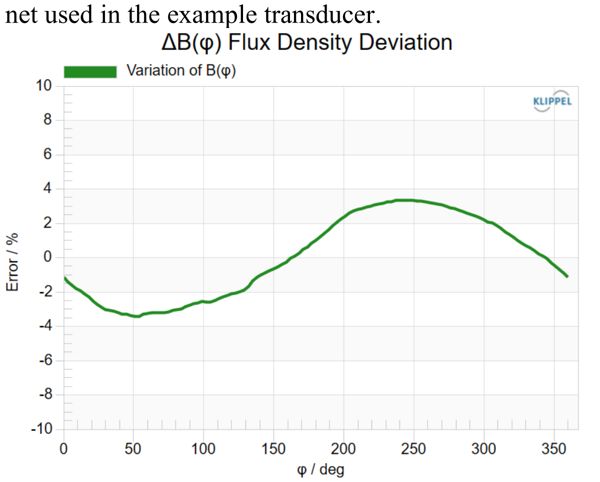

Figure 2: Deviation of the flux density of the magnetic field of the magnet used in the example transducer.

4 Magnetic Measurements

The magnet is an important part of the motor structure that determine the large signal performance of the final speaker. The magnetic properties can be measured with the BFS Sensor, a small Hall sensor, attached to the laser housing of the Multi-Scanning Workbench (Photo 2). This thin sensor fits into the air gaps of most transducer motor structures. It is possible to verify FEM simulations or to inspect magnetic field inconsistencies in the air gap, which can lead to rocking modes. Different coil setups and resulting Bl curves can also be simulated from the resulting B-Field scans. The flux density and flux density deviation of the magnet from the example transducer are shown in Figure 1 and Figure 2, respectively.

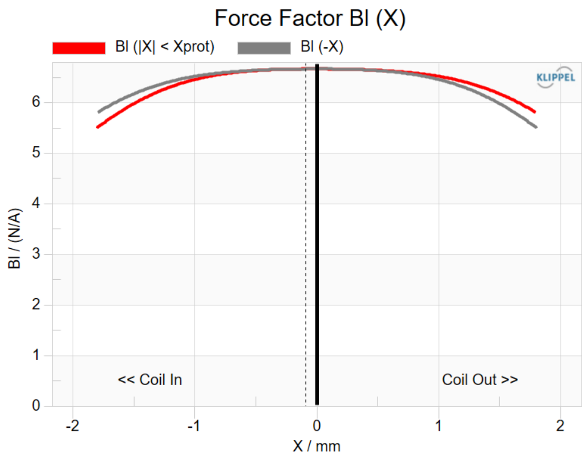

Figure 3: Example transducer Bl(X) curve.

Characteristics	Sensor	Measurement Time
T/S Parameter	Voltage/Current, Laser	1 minute
Nonlinearities	Voltage/Current, Laser	10 minutes
SPL response (any point in 3D half space, directivity, sound power, etc.)	Microphone (single)	5 minutes*
Diaphragm vibration, mode shapes, etc.	Laser	8 minutes*
Magnetic field properties	Hall	8 minutes

*Assuming rotational symmetry

Table 1: Time spent for different measurements of the Example driver using the Multi-Scanning Workbench.

5 Electrical Measurements

There are several different ways to measure the T/S parameters and the impedance curve, including the delta mass and delta compliance methods, that only use electrical signals. However, using a laser displacement sensor in addition to identify the displacement is faster, easier, and more precise [2]. Moving on, with electrical sensors and an optional laser, measuring the lumped parameters of a large signal model and nonlinear curves such as force factor, stiffness, and inductance is a straightforward task [3].

Using the Multi-Scanning Workbench with the laser pointed at the center of the diaphragm, the impedance, T/S parameters, and large signal parameters and curves of the example transducer were quickly obtained (see Table 1). Figure 3 shows a flat and symmetrical force factor characteristic thanks to the underhung voice coil design.

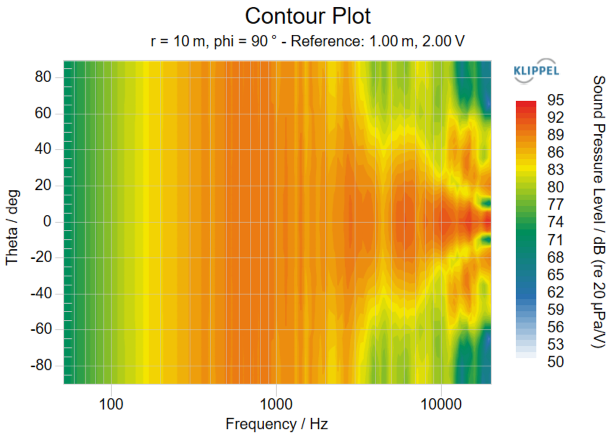

Figure 4: Example transducer horizontal plane contour plot.

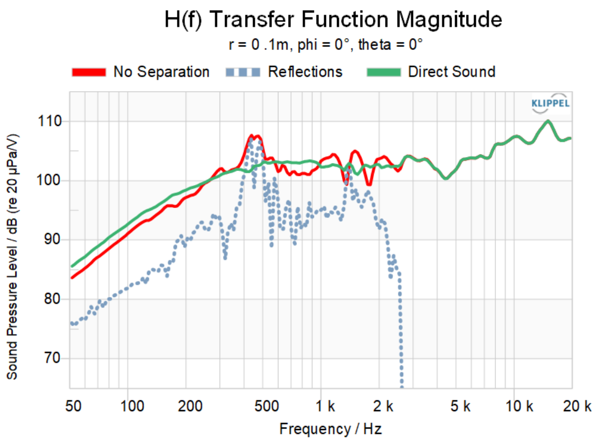

Figure 5: Example transducer measured near field frequency response, direct sound response and separated reflections.

6 Acoustical Scanning

Measuring and analyzing sound radiation to extract sound power and directivity with high angular resolution is usually very time-consuming. However, by performing a holographic measurement with direct sound separation using the SCN Near Field Add-On, a complete scan of the example transducer up to 20 kHz was accomplished in only five minutes (see Table 1) with the assumption of rotational symmetry, which greatly reduces the number of measurement points needed for round drivers placed in round baffles. From this scan, the sound pressure output at any point in 3D half space, in either the near or far field, can be generated. These quick but complete measurement is also perfect for investigating the influence of different grills, horns/waveguides or clamping/mounting options as well as compact complete audio systems such as portable devices. A contour plot of the horizontal sound pressure output (Figure 4) was generated in the far field (10 m distance). This measurement can be done in any normal semi-reverberant room, and the measurement principle is illustrated in Figure 5, where the room and baffle reflections are removed from the measured response to extract the direct sound. In contrast, similar data (1° angular resolution) using turntables and a single measurement microphone would require up to 32,400 measurement points and take between three and four days, leading to a time reduction factor of ~1,000! Aside from the time savings, this measurement would either need to be done in a large anechoic chamber or outside, which leads to other issues such as wind, ambient noise, and temperature variations that can corrupt the data.

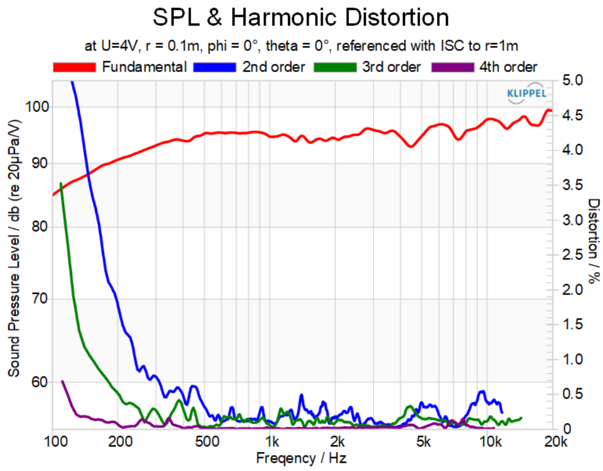

Figure 6: Example transducer fundamental on-axis response and harmonic distortion components.

7 Single-Point Measurements

For some acoustical measurements such as equivalent input distortion or impulsive distortion, also known as rub & buzz, it is always recommended to place the microphone in the near field in order to maximize SNR and sufficiently reduce any room influence [4][5]. For others such as on-axis response and THD, they are usually done at the standard distance of 1 m or farther to ensure the measurement is in the far field. However, after performing an acoustical scan, a (room) correction curve can be generated that compensates for the position of the measurement microphone and any unwanted effects of baffles or non-anechoic rooms. Therefore, the microphone can be positioned in the near field to maximize SNR while measuring in a reverberant room while the virtual evaluation point is at another distance such as in the far field. This means that standard measurements at an evaluation point much farther away, even farther than the physical dimensions of the room, can be done in a normal work or home office while keeping a single microphone in a fixed position. For example, Figure 6 shows the transformed on-axis response and harmonic distortions at 1 m distance, even though the microphone was placed at 10 cm distance.

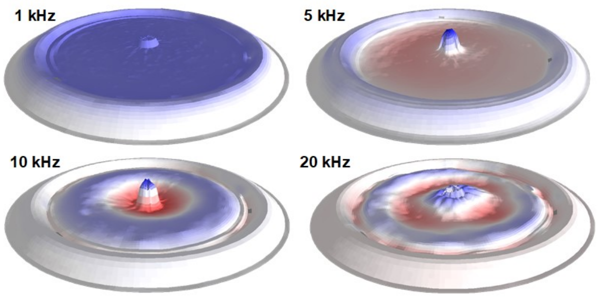

Figure 7: Example transducer diaphragm vibration at multiple frequencies.

8 Mechanical Scanning

Using a laser displacement sensor to assess the diaphragm vibration of a speaker can be very helpful in most applications. After a scan, it is easy to see the contributions of radial versus circular displacement components or how the in-phase, anti-phase and quadrature components are affecting the sound pressure level, which can become complex at higher frequencies due to the modes induced by cone breakup [6]. The vibration data of the example transducer, with several vibration patterns being shown in Figure 7, was obtained in just 8 minutes (see Table 1). Additionally, analyzing rocking modes caused by mass, stiffness or force factor imbalances is especially important for small drivers with simple suspensions [7]. While not expanded upon in this article, these small suspensions can be investigated on the component level as well using the MSPM (Micro Suspension Part Measurement) Bench, which can be attached to the Workbench.

9 Conclusion

The Multi-Scanning Workbench is a physically small but mighty tool for comprehensive speaker testing. Due to the operation across four domains (acoustical, mechanical, electrical and magnetic) as well as the unique advantages of the holographic scanning with direct sound separation, the total space, cost and measurement time can be greatly reduced compared to other solutions that combine different tools for each domain and use anechoic chambers and large baffles. The Multi-Scanning Workbench is ideal for anyone wanting to test speakers in any part of the design phase including

- components (magnet, suspension)
- transducers
- transducers + partial system (with different grills, horns/waveguides or clamping/mounting)
- compact complete systems (such as portable speakers or mobile phones)

even in a non-anechoic environment such as a work or home office.

References

[1] C. Bellman, W. Klippel, “Holographic Nearfield Measurement of Loudspeaker Directivity”, *Audio Eng. Soc.* Convention Paper 9598, (2016 September).
[2] W. Klippel, U. Seidel, “Fast and Accurate Measurement of Linear Transducer Parameters”, *Journal of Audio Eng. Soc.*, Paper 5308, (2001 May).
[3] W. Klippel, “Measurement of Large-Signal Parameters of Electrodynamic Transducer”, *Journal of Audio Eng. Soc.*, Paper 5008, (1999 September).
[4] IEC 60268-21 Sound System Equipment – Part 21: Acoustical (Output Based) Measurements, IEC: 2018
[5] W. Klippel, “Measurement and Application of Equivalent Input Distortion," *Journal of Audio Eng. Soc.*, Vol. 52, Issue 9, pp. 931-947, (2004 September).
[6] W. Klippel, J. Schlechter, “Distributed Mechanical Parameters Describing Vibration and Sound Radiation of Loudspeaker Drive Units," *Journal of Audio Eng. Soc.*, Paper 7531, (2008 October).
[7] W. Cardenas, W. Klippel, “Rocking Modes (Part 2: Diagnostics)”, *Journal of Audio Eng. Soc.*, Paper 9496, (2016 May).

Resources

B-Field Scanner (BFS), Available from: http://www.klippel.de/products/rd-system/modules/bfs-b-field-scanner.html

In-Situ Compensation (ISC), Available from: http://www.klippel.de/products/rd-system/modules/isc-in-situ-compensation.html

Micro Suspension Part Measurement (MSPM), Available from: http://www.klippel.de/products/rd-system/modules/mspm-micro-suspension-part-measurement.html

Near Field Scanner System (NFS), Available from: http://www.klippel.de/products/rd-system/modules/nfs-near-field-scanner.html

Scanning Vibrometer System (SCN), Available from: https://www.klippel.de/products/rd-system/modules/scn-scanning-vibrometer-system.html

SCN Near Field Add-On (SCN-NF), Available from: https://www.klippel.de/products/rd-system/modules/scn-nf-scn-near-field-add-on.html