

On the Velocity Distribution at the Interface of Horn Driver and Horn

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Introduction

For numerical simulations (boundary element method) of horns, the distribution of velocity at the horn throat is required as boundary condition. This velocity distribution represents the wave radiated by the horn driver into the horn throat so that the horn can be described independent from the horn driver. For frequencies below the first higher order mode, a plane wave is assumed. Usually, the plane wave approach is also used for the higher frequencies as the shape of the wave front radiated by the horn driver is not known. This can cause an error in simulation results, e.g., the simulated frequency response may deviate from a measured one. To improve the accuracy of numerical simulations, a specific distribution of velocity and pressure has to be used. To achieve more information about the required conditions, the pressure distributions of different horn driver/horn combinations are measured at the interface between horn driver and horn. Several questions arise:

- Does the velocity distribution change when coupling one driver to different horns?
- Is the velocity distribution dependent on the horn driver used?
- Is it possible to synthesize a distribution from these measurements fitting most horn drivers?

A wave front synthesized from these measurements should allow a more precise description of the interface horn driver/horn and, thus, increase simulation accuracy at high frequencies. Measurements and simulations are compared in order to verify this method.

Measurement setup

The boundary element method requires the velocity for each node of the mesh perpendicular to the mesh elements which describe the cut plane between horn driver and horn (see fig. 1). This direction is the z-axis. The cut plane is described in coordinates of x and y. The pressure was scanned in adjacent planes in a short distance. From the pressure gradient, the velocity can be calculated for each node by eq. (1).

$$v_z(\omega) = - \frac{1}{j\omega\rho_0\Delta z} (p_2(\omega) - p_1(\omega)) \quad (1)$$

Δz = distance of the measurement planes

$p_2(\omega) - p_1(\omega)$ = pressure difference

The measurement setup for scanning the x-y-plane is shown in fig. 2. The horn driver is moved by stepping motors to the node coordinates. The excitation of the driver, measurement of the pressure, and the motors

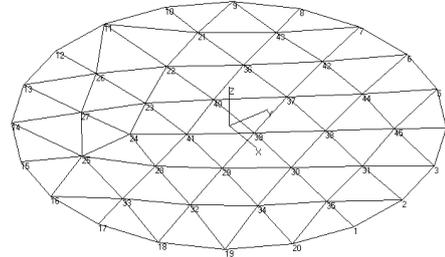


Figure 1: Triangular mesh describing the junction of driver and horn.

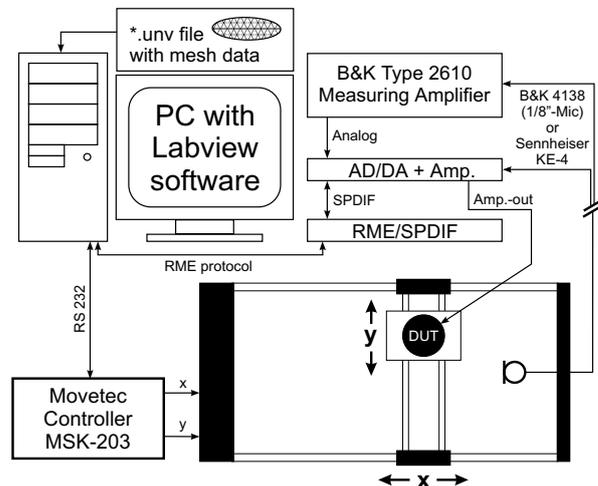


Figure 2: Measurement setup

are controlled by a PC. The distance Δz of the planes should be selected carefully. On the one hand, a short distance is needed to cover the full audio frequency range. On the other hand a minimum distance is needed to increase the signal-to-noise ratio at low frequencies[1]. A distance of $10mm$ was used which is a good compromise. The error made at $20kHz$ is approximately $2dB$. As this error is made at every measurement point, the resulting shape of the wave form is not affected.

Results

By now, about 50 combinations of horn drivers with and without horn were investigated using the method described above. Most of the systems had a 2"-junction diameter, but also 1.4" and 1" drivers were measured. Fig. 3 shows the measured velocity distribution of a 2" horn driver (without horn) which is typical for most of the measured transducers. Three frequency ranges can be distinguished:

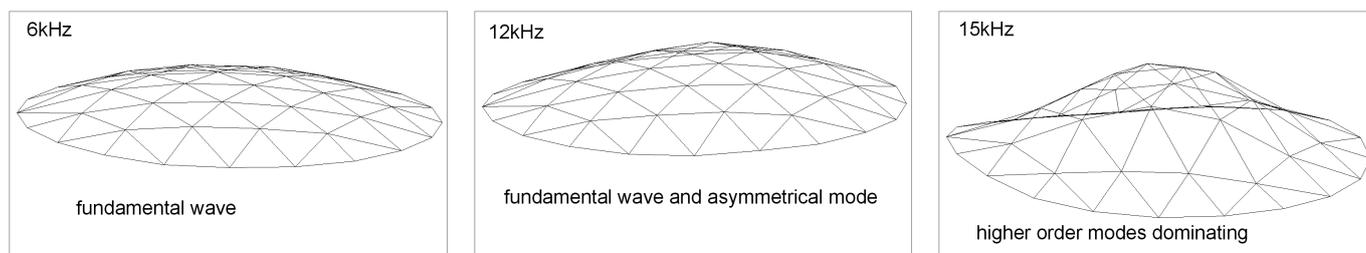


Figure 3: Measured velocity distribution of the Electro Voice DH1A driver without horn at $6kHz$, $12kHz$ and $15kHz$

1. 0 – $11kHz$ fundamental wave
2. 11 – $14kHz$ fundamental wave and superposed first higher order mode
3. 14 – $20kHz$ higher order modes dominating

Although higher order modes are possible below $11kHz$ (for example at $4kHz$ in a $2''$ -junction), the fundamental wave (plane wave) dominates the behaviour of the driver. Frequency range 2 is still dominated by the fundamental but the first higher order mode is superposed to the fundamental. The transition frequency from range 2 to 3 is depending on the driver but sometimes may occur at other frequencies. The excitation of higher order modes obviously falls together with the internal membrane breaking up into higher order modes. The observed velocity distributions were nearly independent of being measured with or without a horn coupled to the driver. Thus, it is possible to use the same distribution for all drivers and horns. From this results, an important

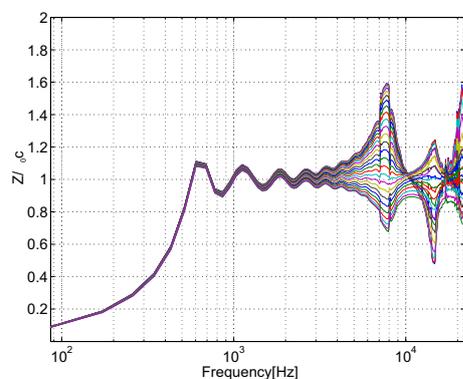


Figure 4: Simulated throat impedance of a $2''$ -tractrix horn

conclusion can be derived: Higher order modes within simulation results should be ignored as they, normally, are not predominant in the frequency range where no structural modes occur on the membrane! Fig. 4 shows the simulated throat impedance of a $2''$ -tractrix horn for each node. Although a plane wave distribution was used as boundary condition, two higher order modes appear at $8kHz$ and $14kHz$. Using other excitation distributions also yields higher order modes in the results. Normally, these do not occur in measurements as they are not excited by a real horn driver. Fig. 5 shows a measured and two simulated frequency responses. One frequency response was simulated using the integrated distribution as horn throat impedance. The other result was calculated

using a synthesized impedance distribution ignoring the modes at $8kHz$ and $14kHz$. The example shows that the

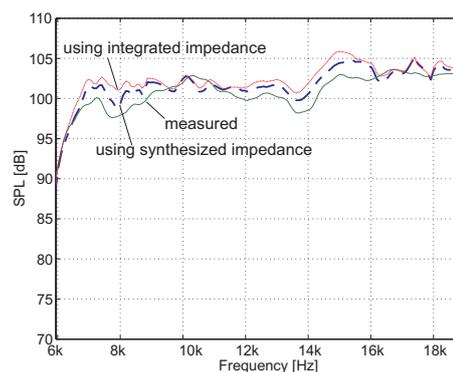


Figure 5: Simulated and measured frequency response of a $2''$ -tractrix horn with BMS 4592-16 driver

calculated response using the synthesized distribution is about 2dB closer to the measured one.

Conclusions

A measurement setup was presented that allows accurate measurements of pressure and velocity distributions within the junction area of horn driver and horn. The results show that the fundamental wave dominates the acoustic behaviour up to the frequency where the membrane starts breaking up massively into higher order modes and, thus, exciting modes within the junction area. Furthermore, this behaviour is nearly independent of having a horn coupled to the driver. Thus, when using numerical simulation results to calculate combinations of drivers and horns, the impedance distribution has to be synthesized to fit real life conditions. Higher order modes that are normally not excited have to be ignored within the simulation results. This leads to a more accurate result within the critical frequency bands.

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References

- [1] F.J. Fahy. *Sound Intensity*. Elsevier Science Publishers Ltd, 1989.