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Acoustic Decoupling Device in Coaxial Compression Driver

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ABSTRACT

Coaxial loudspeakers are designed to reproduce a broad frequency range while keeping a compact form factor. Correct driver integration requires the engineer to properly deal, at the design phase, with the presence of multiple radiating units and with the interference between their acoustic emissions; this is essential to obtain a smooth response and a wide crossover region suited to flexibly accommodate different filter designs. Due to the presence of multiple phase plugs, recently-appeared two-way coaxial compression drivers require particular care to ensure excellent acoustic performance at short wavelengths. Adding an appropriate decoupling device in the structure allows effective management of the acoustic emission of the two transducers with respect to each other, improving response regularity and increasing the available bandwidth for the crossover versus historical approaches.

1 Introduction

Coaxial loudspeakers host in the same unit two or more drivers, with their acoustic centers aligned along the same axis. This configuration brings several advantages, the most noticeable of which is the possibility to reduce the size, weight and cost of the system with respect to the case of multi-way systems made up of different transducers, especially when multiple voice coils share the same magnetic circuit [1]. Compact and light systems able to reproduce a broad frequency range can thus be obtained. The acoustical advantages are manifest: the reduced distance among the acoustic centers of the different units is a welcomed feature as it helps to integrate the drivers together, obtaining smooth dispersion patterns with reduced lobing using simple crossover filter designs [2].

In recent years, two-way coaxial compression drivers have been making their appearance on the market, arousing interest due to both their high efficiency and the possibility to control directivity over most parts of the spectrum using appropriate horns.

Three-way coaxial designs (where a coaxial compression driver and a woofer are coaxially integrated) are also available, further exploiting the advantages of this technology and allowing to cover almost the full acoustic spectrum with a single unit.

The very same aspects making the coaxial configuration so interesting at the same time constrain design possibilities: the presence of multiple radiating units sharing space can dictate unusual geometric choices, and the need to efficiently reproduce a wide frequency range demands managing dimensions down to the smallest wavelengths to prevent phase issues. Care is required to accurately reproduce frequencies in the crossover region: for a controlled transition between the two units, which in turn facilitates crossover filter realization, it is important to ensure their mutual independence, so that no reciprocal shadowing or acoustic load modification occurs and the acoustic emissions don’t interfere destructively [3], [4].

To optimize the final object in terms of compactness, directivity, usable frequency range, power rating, efficiency and cost, the designer thus needs to take into account and have control on a broad list of parameters. This task is overcome by relying on the appropriate physical description of the transducer behavior, exploiting the power of simulation software and performing measurements in different acoustic loading conditions in order to separate electromagnetic, mechanical and acoustical phenomena.
To illustrate this, results of the research carried out at B&C Speakers during the development of a two-way coaxial compression driver are presented.

2 Acoustic impedance mismatch in coaxial compression drivers

Coaxial compression drivers bring the advantages of the coaxial approach into a very compact package: featuring two compression drivers, each with a dedicated membrane driven by a dedicated voice coil and loaded with a dedicated phase plug, they allow reproduction of nearly six octaves with the high efficiency typical of compression drivers.
Though the two drivers have separate phase plugs, their outputs need to merge somewhere, either at the throat or before that point, so that a single horn can be used to load the speaker. Waves propagating into the acoustic channels of one unit thus experience an abrupt change in the surrounding conditions as they transition the new acoustic paths suddenly made available by the phase plug of the other unit: the physical relationship between air pressure and velocity gets modified and both acoustic reflection and transmission phenomena take place.
These effects take the name of "acoustic impedance mismatch" and are always present whenever, along their transmission paths, acoustic waves meet obstacles or modifications in the propagation environment, where these changes in the geometry have dimensions comparable to the acoustic wavelength [5, chap. 6]; when they are of particular intensity, dips and peaks are visible in the frequency response of the radiating unit and sometimes also in its electrical impedance.

3 Simulations

Simulation software can greatly help the designer to minimize unwanted phenomena such as acoustic impedance mismatch while keeping all the other acoustical and geometrical features of the product unaltered, allowing to easily assess the effect of any change introduced in the structure, properties and materials without any need to build prototypes.
Finite element simulations performed during the design phase of the B&C Speakers DCX464 two-way coaxial compression driver immediately clarified how the acoustic impedance mismatch due to the two phase plugs combining would have impaired the acoustical performance: the high frequency unit response presented multiple dips and peaks and the crossover region between the two radiators had limited width.
A technical solution was thus conceived, which, after some iterative rounds of simulation, prototyping and optimization activities, evolved in the decoupling device now integrated in the product family.
Simulated acoustic responses with and without the decoupling device are shown in Figure 1 for the low frequency and the high frequency unit (in the following indicated as "LF unit" and "HF unit", respectively). In simulations, the speaker was supposed to be coupled with a horn with logarithmic profile. Sound pressure levels in Figure 1 are relative to 20 μPa.

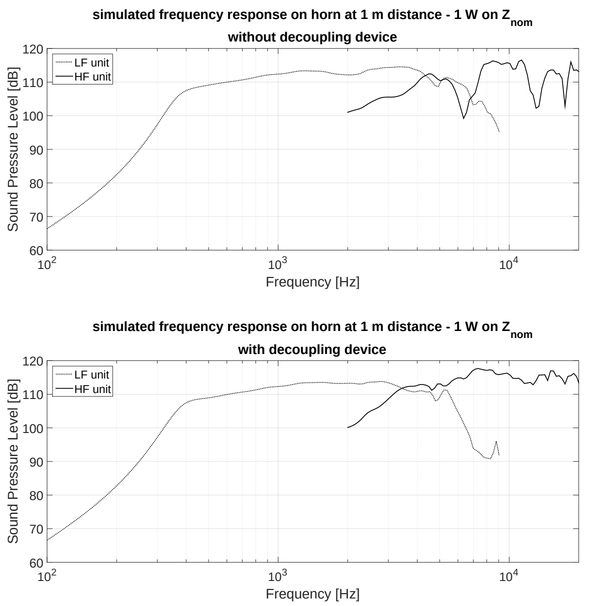

Fig. 1: Results of simulations on the geometry of B&C Speakers DCX464 coaxial compression driver, showing the detrimental effect of acoustic impedance mismatch on its acoustical performance.

4 Measurements

In the following paragraphs, the measured electrical and acoustical performance of both low frequency and high frequency units of the B&C Speakers DCX464 is presented. In all tests, stimulus was supplied to one unit only at a time, short-circuiting the other one.
In order to separate mechanical effects from acoustical ones, measurements were performed in different acoustic loading conditions, namely placing the driver in a vacuum chamber and coupling it to a horn in an anechoic chamber.
In order to show the impact of acoustic impedance mismatch on performance, measurements were performed both leaving the phase plugs merging freely ("configuration 1") and putting a decoupling device in the structure to minimize the effect ("configuration 2").
Configuration 2 reflects the solution actually featured in the production DCX464.

4.1 Electrical impedance

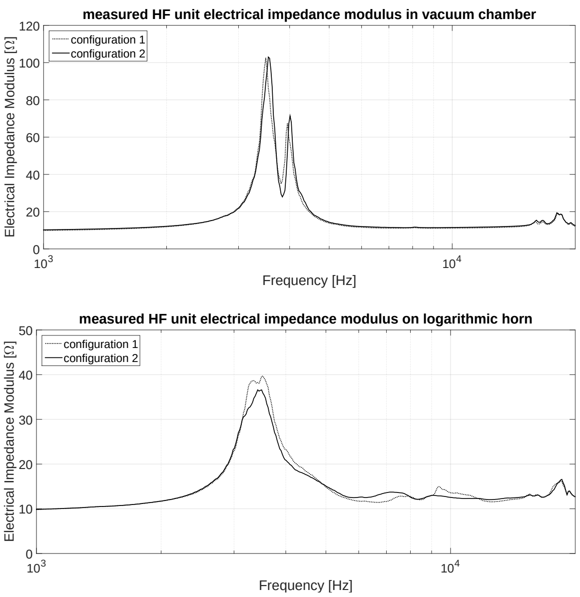

Fig. 2: Measured HF unit electrical impedance modulus with the driver placed in a vacuum chamber (top) and coupled with a horn with logarithmic profile and 350 Hz cutoff frequency (bottom).

As anticipated, a direct method to identify acoustical aspects consists in comparing electrical impedance measurements performed on the driver in different acoustic loading conditions, such as placing it in a vacuum chamber versus coupling it with a horn in air. Due to the absence of air in the chamber, no acoustical phenomena can take place (in particular, no acoustic radiation can be produced and no acoustic impedance mismatch can exist) and all observed effects are thus either electromagnetic or mechanical in nature. Since the decoupling device should affect neither the electromagnetic nor the mechanical behavior of the two units, no appreciable difference is expected to be visible between configuration 1 and 2 in the vacuum chamber case; conversely, its effect should manifest when the driver is placed in air and coupled with a horn.
Figure 2 confirms this hypothesis: with the driver placed in the vacuum chamber, measured results for the high frequency unit in the two configurations almost lie on top of each other, while there are clear differences in the 7 kHz region when the driver is coupled with a horn. This suggests the decoupling device affects the speaker acoustic behavior at those frequencies, while leaving almost unaltered the electromagnetic and mechanical ones.

4.2 Acoustic frequency response

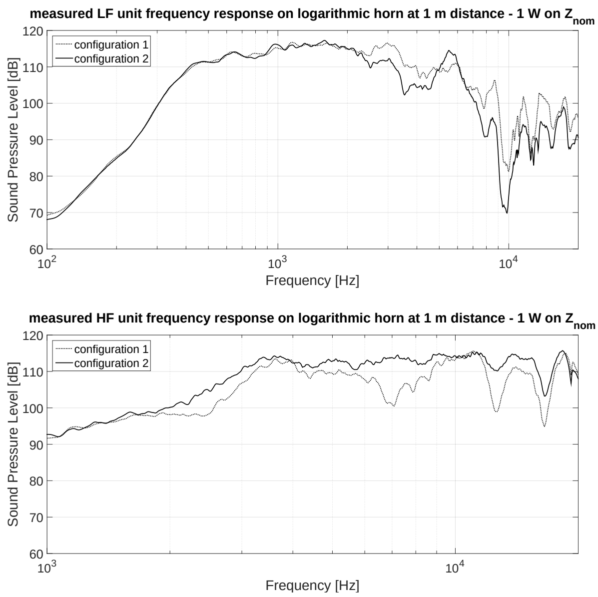

Fig. 3: Measured LF and HF units frequency response coupling the driver with a horn with logarithmic profile and 350 Hz cutoff frequency, before and after the decoupling device introduction.

On-axis frequency response was measured in an anechoic chamber, coupling the driver with a horn with logarithmic profile and lower cutoff frequency of 350 Hz; the microphone was placed at 1 m distance from the horn mouth and supplied rms voltage to the two units was 4 V (1 W on 16 Ω nominal impedance). Sound pressure levels in figures are relative to 20 μPa.

Figure 3 shows the introduction of the decoupling device solves the problem at 7 kHz, additionally improving the high frequency unit response regularity throughout the whole working range, most notably in the 2.5 kHz and 12 kHz regions, as simulation had suggested.

Improvements in terms of crossover region bandwidth can be appreciated in Figure 4.

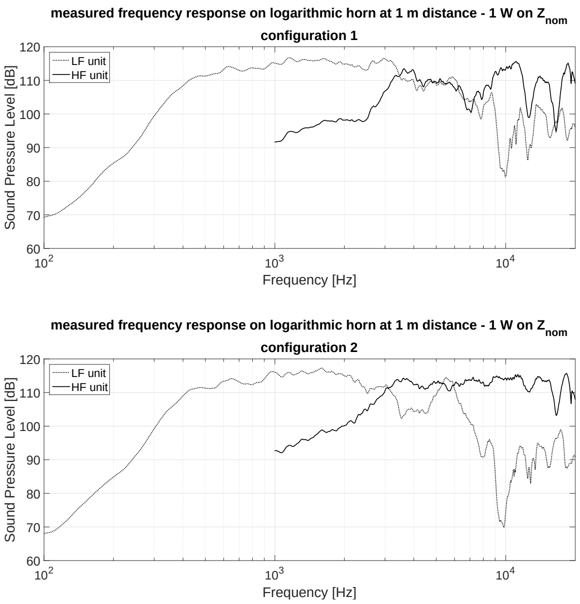

Fig. 4: Comparison between response regularity and crossover frequency range width without decoupling device (configuration 1, top) and with decoupling device (configuration 2, bottom).

5 Summary

When coupled with appropriate horns, coaxial compression drivers offer high efficiency and controlled directivity over most parts of the spectrum in a small form factor and are thus extremely appealing to the user.

The very same aspects making coaxial configuration so interesting, however, constrain design possibilities and care must be dedicated in the design phase to ensure high performance of the speaker.

In particular, providing a geometry to merge the two units phase plugs together while keeping acoustic impedance mismatch effects under control is of the highest importance to obtain both a regular response and a wide crossover region, suitable to accommodate multiple filter designs.

Results of simulations and measurements performed at B&C Speakers during the development of a two-way coaxial compression driver demonstrate how introducing a decoupling device in the structure can reduce the mutual influence between the low and high frequency units with minimal design compromises.

References

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