The Naim Balanced Mode Radiator

The Naim Ovator Bass Driver

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The Balanced Mode Radiator (BMR)

A BMR is a circular flat panel loudspeaker that covers the whole audio bandwidth with exceptionally wide dispersion. It employs components similar to those that are used in conventional loudspeakers. These are:

- A surround attached to the rear of the panel to suspend it to the frame.
- A voice coil coupled straight to the panel and centred via the spider.
- A moving-coil actuator that provides motive force.

In a traditional loudspeaker, the diaphragm acts as a ‘rigid piston’ at low frequencies, but turns into a multi-modal object, when approaching its so called ‘break-up region’. In a BMR there is no ‘break-up region’. Instead, a limited number (usually 2-4) of evenly spread modes are carefully positioned within the frequency band. The modal, bending-wave operation starts in the frequency range where the piston-like operation of the panel would otherwise cause the driver to beam. The result is a drive unit that operates like a piston at low frequencies but becomes a bending wave device at high frequencies. Thanks to the bending wave operation the drive unit demonstrates wide dispersion even at high frequencies. Acoustically, the behaviour of a BMR approximates to the ideal ‘point source’.

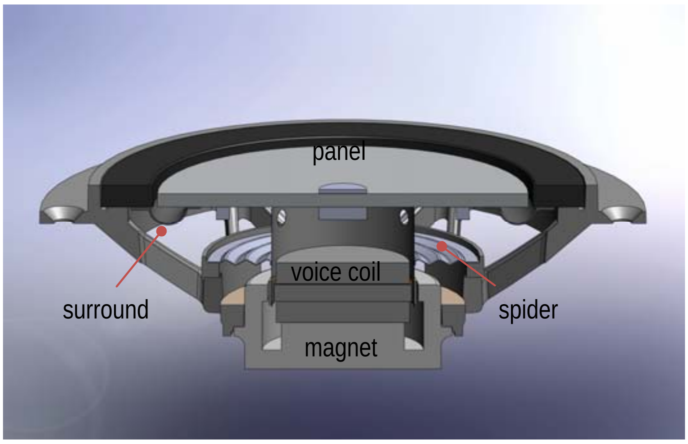

Fig. 1 Cross-section of Naim BMR

How does it work?

The underlying operating principle of a BMR can be explained on the basis of simulation results derived for an isotropic disk of 85mm panel diameter. The disk is driven at its 1st nodal line (0.68 x panel-diameter) with an ‘ideal’ force that has no associated mass or damping.

Free disk driven by ‘ideal’ force

The resulting on-axis frequency response is shown in the top diagram to the right (red curve). One can see that under these conditions the flat disk shows a naturally balanced response with only small dips at the 2nd and the 3rd mode (The 1st mode is fully suppressed, because the panel is driven at its nodal line!).

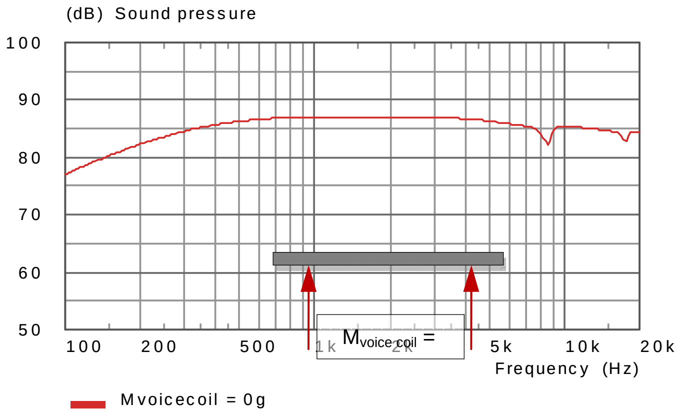

Fig. 2

Free disk driven by ‘real’ force

Of course, in the real world there is always a mass associated with the voice coil, which generates the force on the panel. Here, a voice coil mass of 1g is assumed for the simulation. The blue curve in the middle diagram to the right shows that even such a small mass can destroy the natural balancing of the disk.

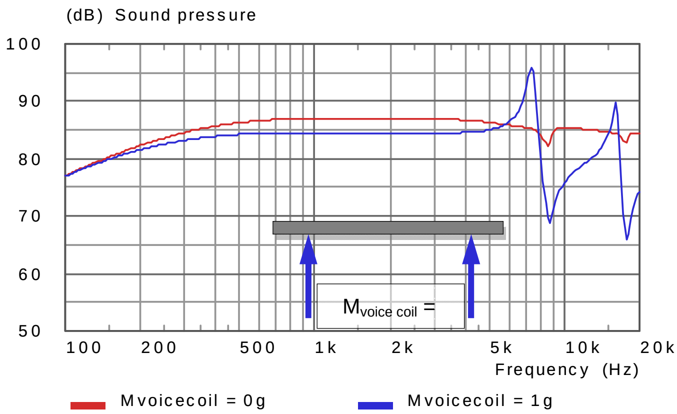

Fig. 3

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Balanced disk driven by 'real' force

Now, additional masses are placed left and right of the voice coil at pre-determined diameters. These so-called balancing masses restore the acoustical behaviour of the free disc. Note that the masses are not normally added at the centre or the edge, since these are always anti-nodes of all modes.

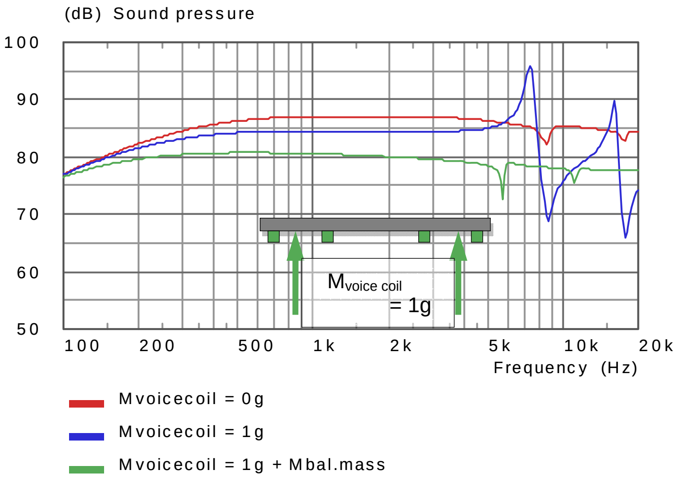

Fig. 4

From the above exercises it becomes clear that the free vibrating disk represents the acoustic reference of the BMR. It is only when a mass-carrying voice coil is attached to the disk that its previously faultless acoustic behaviour is disturbed. The original performance of a free disk can be restored by balancing the voice coil mass with additional masses. It is this operating principal that gave the "balanced mode radiator" its name.

Technical Aspects

Conventional loudspeaker

Evaluation is a fundamental part of the creation of any new loudspeaker. Traditionally, a uniform response over the audible range has been an obvious aim for the designer. This is usually verified by acquiring the on-axis response together with one or two off-axis responses. The on-axis response is measured in front of the loudspeaker level with the tweeter at a distance of 1 to 2m. The off-axis responses are measured at a similar height except that the microphone is rotated to a distinct angle (e.g. 15°, 30° ...). When dealing with conventional drive units this method is sufficient since the on- and off-axis responses look very much alike, except for the level which drops constantly with increasing measuring angle.

Fig. 5 and 6 show response curves for a typical 2-way loudspeaker, consisting of a 165mm bass/midrange driver and 25mm dome-tweeter. The crossover frequency is around 3.0kHz. Figure 5 shows selected frequency response curves at 0°, 30°, 60° and 90°. Figure 6 shows the horizontal frequency/directivity plot, where the level is colour-coded and plotted over frequency against measuring angle (range -90° – +90°).

The frequency/directivity plot reveals that with increasing frequency the 165mm bass/midrange driver starts projecting the sound more to the front. When the tweeter takes over at around 3.0 kHz the directivity widens again until the tweeter itself becomes directional above 8.0 kHz. The general characteristic of the frequency response under various angles remains unchanged, so that the on-axis frequency response gives already a good indication of the tonal balance of the loudspeaker.

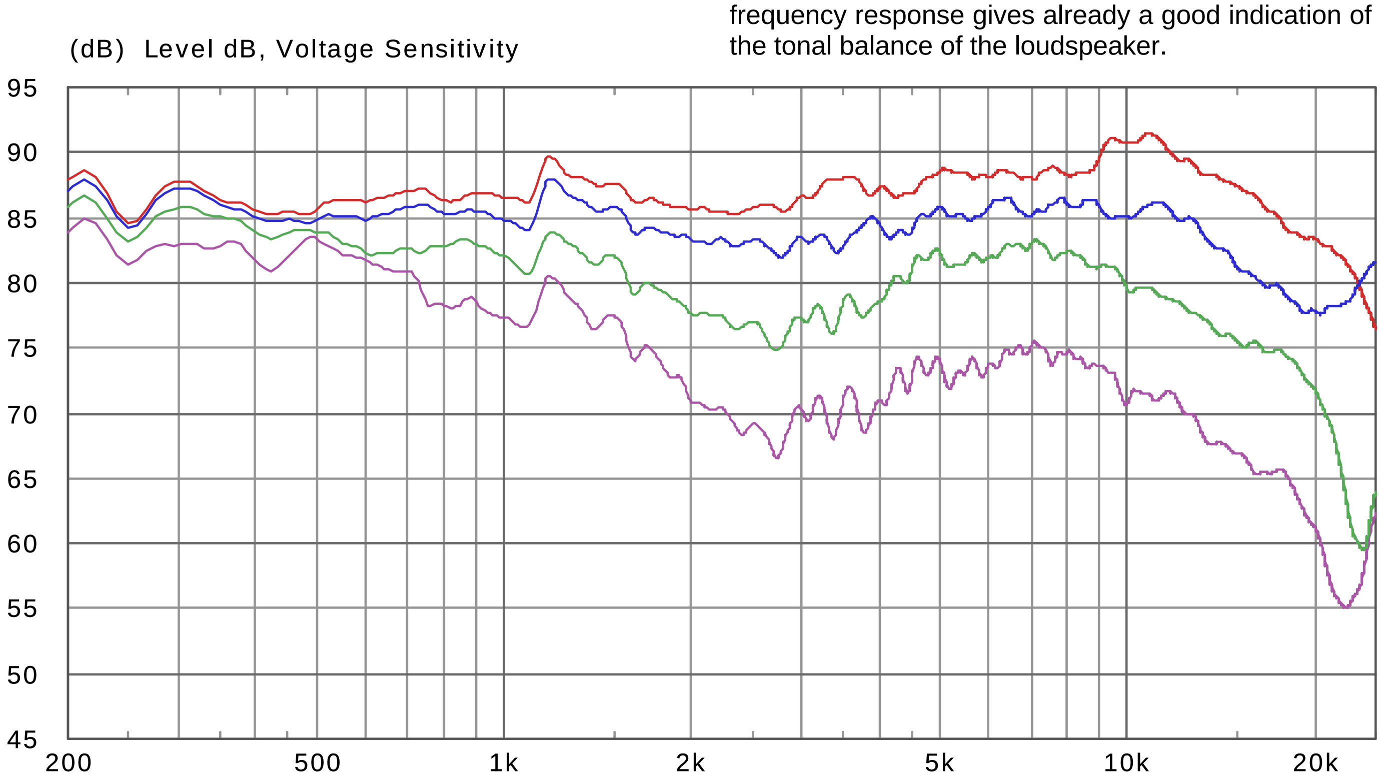

Fig. 5 On- and off-axis SPL of 2-way speaker @ 0°, 30°, 60°, 90°.

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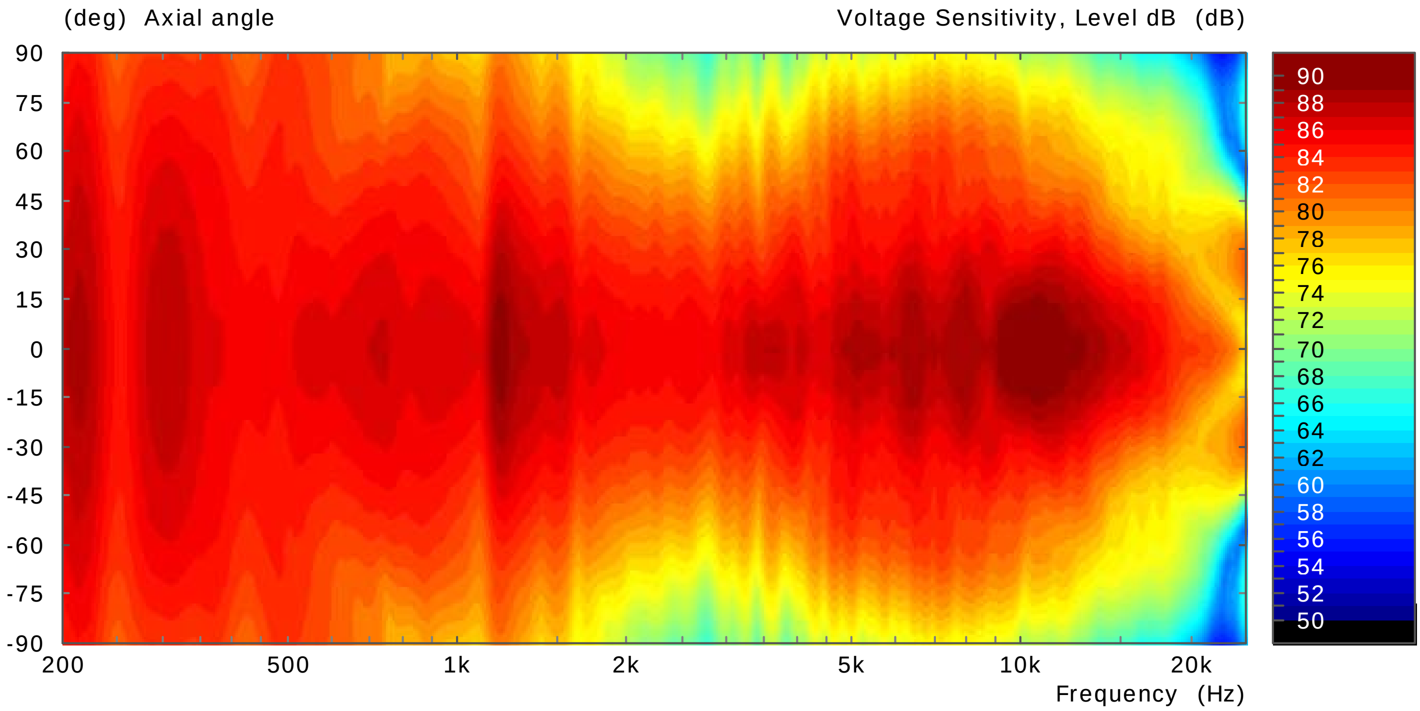

Fig. 6

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Balanced Mode Radiator

In Fig. 7 and 8 the on and off-axis responses and frequency/directivity plot the are shown for the Naim BMR. From the colour-coded directivity plot one can see that the BMR radiates much more broadly than the 2-way loudspeaker discussed above. Due to its combination of piston-like operation at low frequencies and bending wave radiation at higher frequencies, the drive unit sustains a very broad radiation characteristic up to 25.0 kHz. Even at 90° measuring angle the high-frequency level remains only 10dB below the on-axis reference level.

Since the BMR unit can operate down to 100 Hz, the system designer is free to choose a crossover frequency that fulfils the requirements of the cabinet geometry and the low frequency driver.

What is more important however is that the on-axis frequency response curve is no longer an accurate indicator for the tonality of the loudspeaker. In fact during the development of the Naim BMR it became clear that the on-axis response is as good, or bad, as any other single frequency response measured at any arbitrary angle.

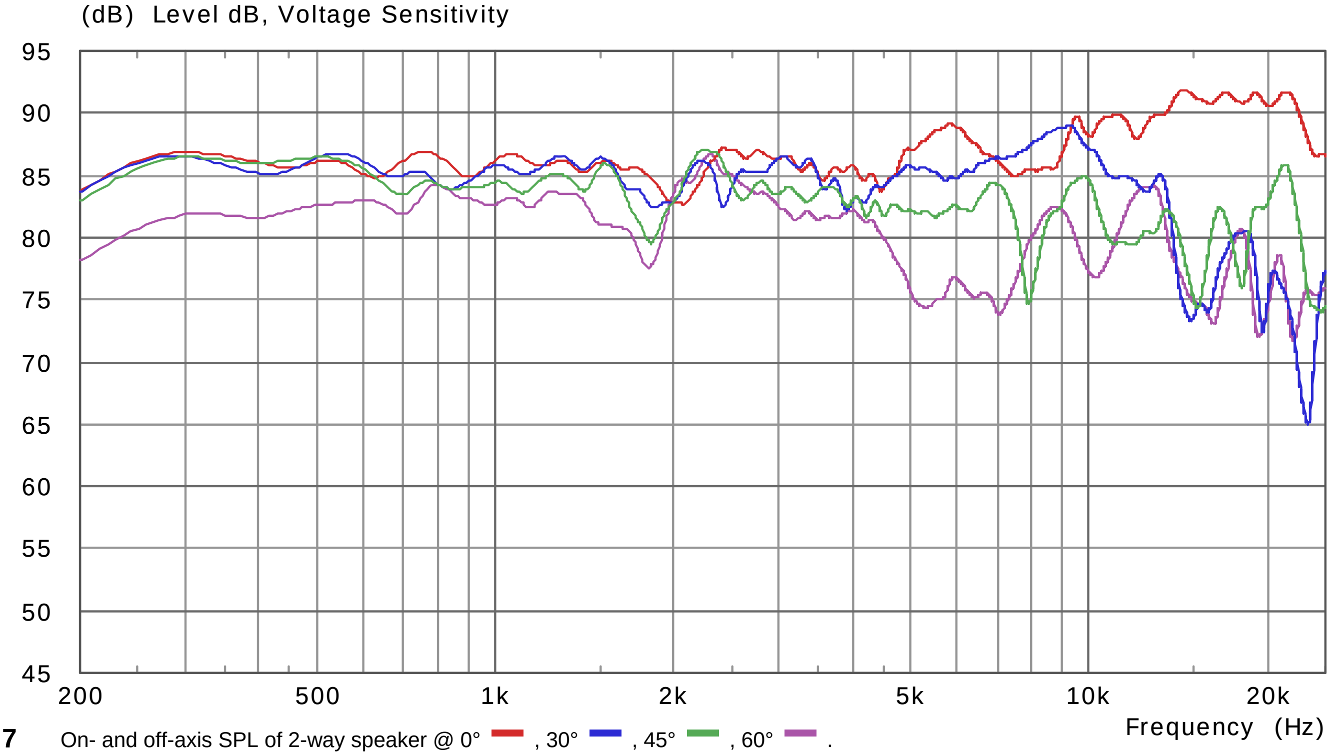

Fig. 7 On- and off-axis SPL of 2-way speaker @ 0° , 30° , 45° , 60° .

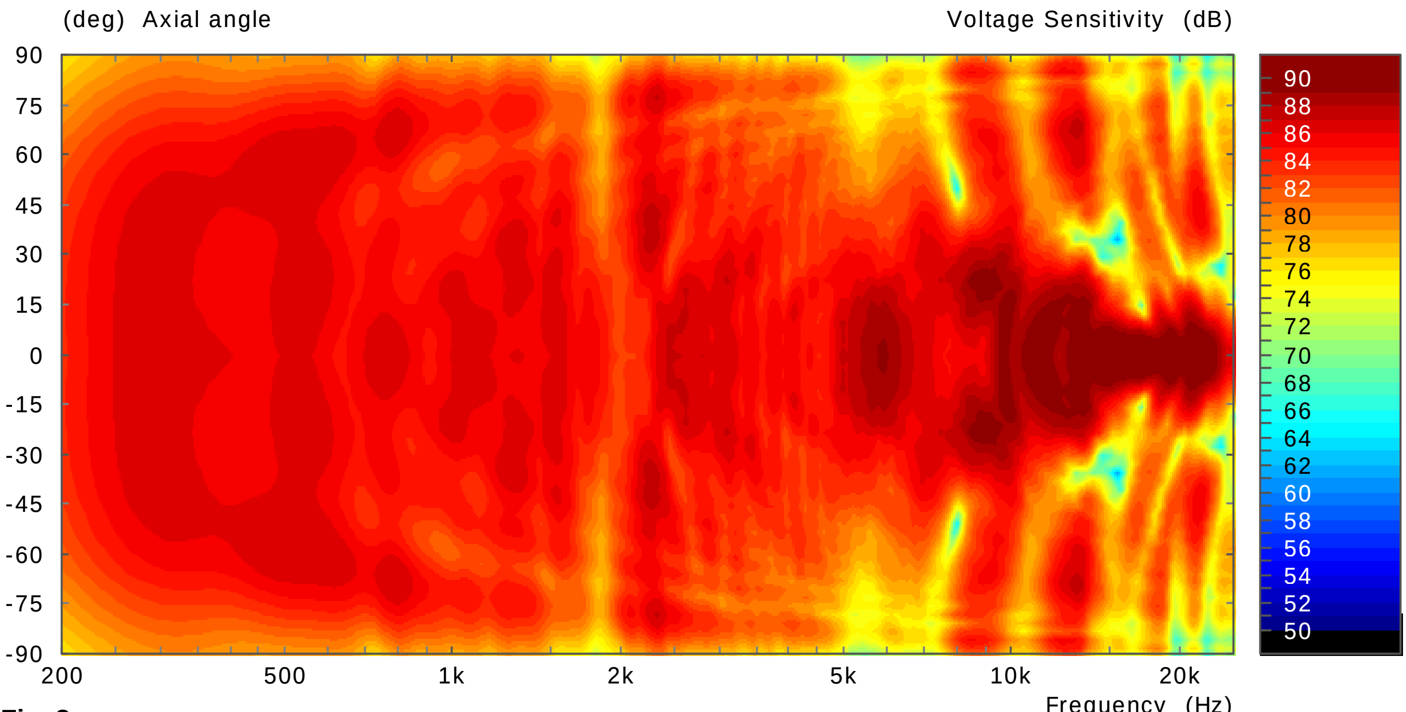

Fig. 8

So what is a meaningful measure for a BMR?

There is a contradiction. A smooth on-axis response is desirable, since it defines the tonality of the direct sound when sitting in the near field of the loudspeaker. But the BMR's broad radiation makes it necessary that the off-axis radiation should be free of any strong side-lobes, otherwise the sound reflected back of the sidewalls or ceiling will cause audible colorations.

Thus for a BMR-based loudspeaker it is necessary to measure both the horizontal and vertical frequency dispersion and the acoustic power. The acoustic power (or sound power) response describes the total acoustic energy the loudspeaker radiates into the room. It is the only measure that can be used to characterise loudspeakers with broad dispersion or a large radiating area – like large dipole loudspeakers, omni-directional loudspeakers or BMR-based loudspeakers. A meaningful assessment of a BMR-based system can only be performed on the basis of a range of measurements, including the on-axis response, the acoustic power response and dispersion data acquired for the horizontal and vertical plane.

It is obvious that the acquisition of these data takes more time than the measurement of a single response curve. Consequently the development time for a BMR is considerably longer than the time required for a conventional cone-based woofer or dome-tweeter, since each step in the development cycle needs to be verified by all the above mentioned measurements.

The Ovator S-600 and what is so special about it

As one could guess from the above the Naim BMR has come a long way. In fact, the development of the BMR took more than three years. Every part has undergone an extensive evaluation regarding its influence on the sound. This includes the motor, the membrane (panel), the surround, the voice coil and the spider.

The motor

Although the unit operates only above 400 Hz and thus will experience excursion values of less than 1mm, the motor was intensively optimised using finite-element-analysis (FEA). Several aspects needed to be addressed during the development. First of all, the motor has to generate a certain amount of magnetic flux density in the air gap. Together with the voice coil, the flux density determines the final sensitivity of the drive unit. Another requirement for the motor was that it should not interfere acoustically with the sound radiated to the rear. Thus a very compact form factor was mandatory. Furthermore the motor should provide sufficient cooling so that the voice coil's operating temperature remains low. This prevents the driver from running into thermal compression.

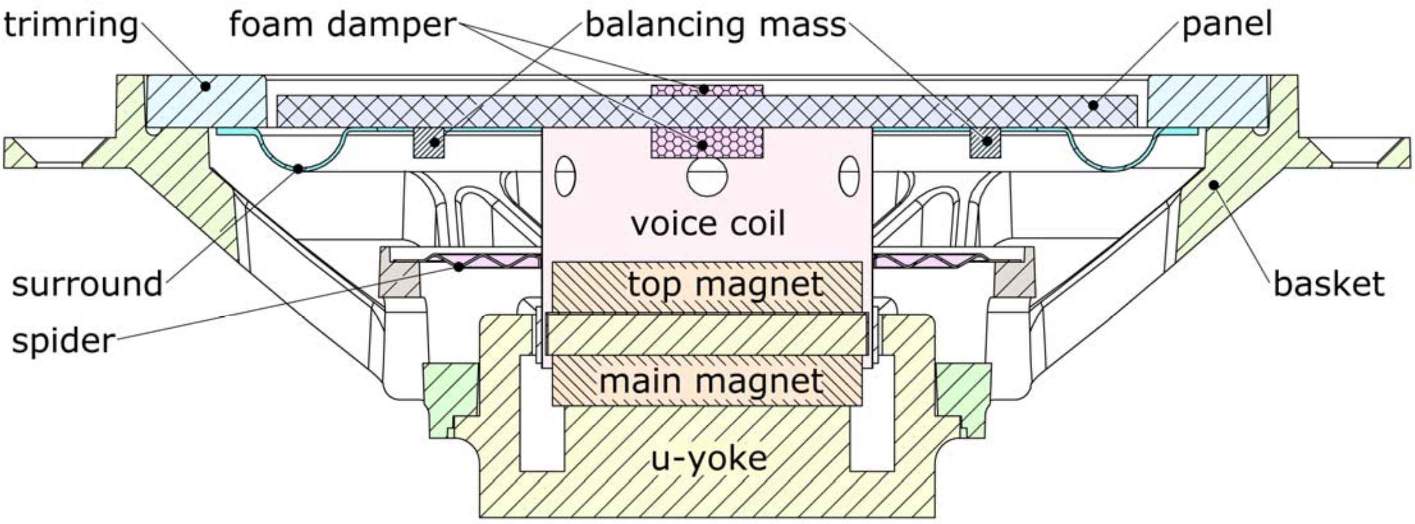

Fig. 9 Cross-section view of Balanced Mode Radiator.

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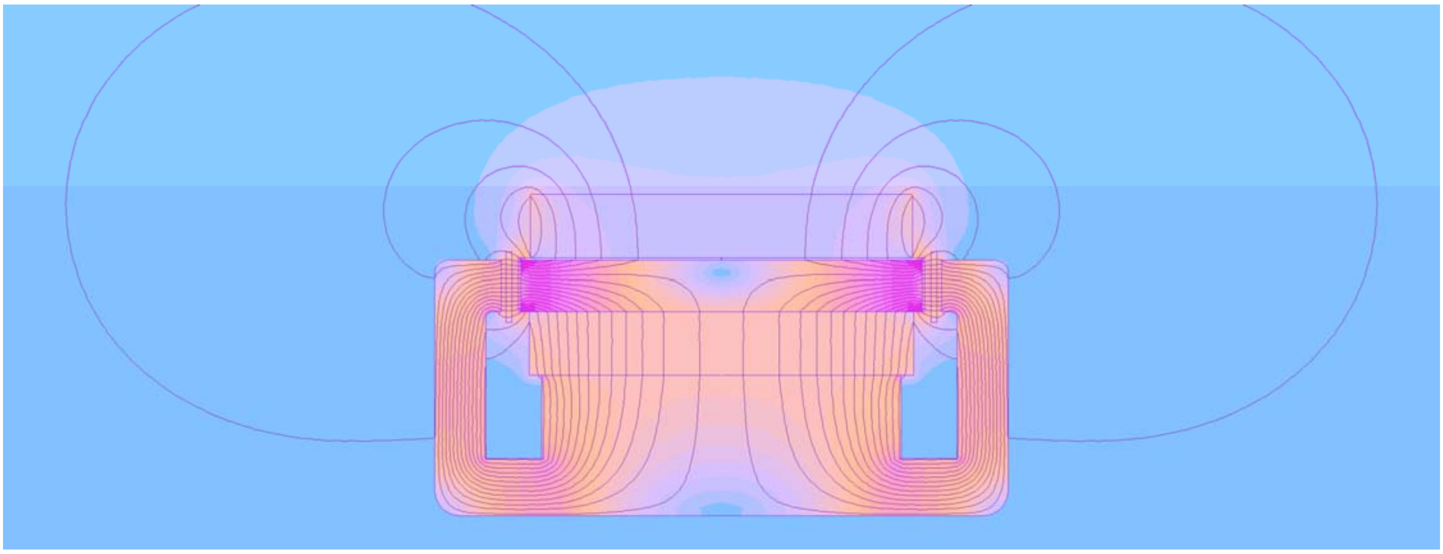

Fig. 10 Flux density plot of BMR magnet system

The final motor consists of a double neodymium magnet configuration positioned inside the voice coil. Neodymium was chosen because of its ten-time higher energy product compared to ferrite. This allows for a very compact design with the two magnets placed above and below the pole piece. From a magnetic point of view the metal u-cup could have been smaller, but the deep shape assures a high thermal capacity so that heat is quickly dissipated from the voice coil into the metal avoiding thermal saturation of the metal part. A copper shield that covers the pole piece helps to reduce distortions but also controls the amount of high frequency output, due to its influence on the impedance.

The voice coil mass represents a crucial design variable in a BMR-design. The lower the mass, the less additional balancing masses are required. Thus the coil is wound from copper-clad-aluminium instead of pure copper.

After evaluating a range of possible former materials the final choice was made in favour of glass fibre, which turned out to give the best sounding result. Technically its good heat-resistance and very good stiffness make it an ideal choice of a BMR.

The membrane (panel)

The membrane material has a large impact on the sound – if not the largest. Various panel combinations were evaluated before settling on a composite material based on a Nomex-honeycomb-core covered by paper skins on either side. This material combines low weight with good damping and high stiffness. The panel's stiffness is chosen such that the first bending mode is located in the frequency range where the panel would otherwise start to beam the sound.

The surround

In a conventional cone-based drive unit the suspension fulfils two functions. At low frequencies it serves as a suspension that controls the movement of the membrane, while at high frequencies it terminates the membrane in order to control the break-up modes. In a BMR used as pure mid/high frequency driver, the requirements are completely different. With 1mm maximum excursion, there is no need to control the movement at low frequencies and when the panel becomes modal, the surround acts as a balancing mass. Thus the weight, diameter and damping of the surround is chosen such that good control for all bending modes, in particular the first one, is achieved.

How BMR might work in more rooms

Compared to conventional, more directional loudspeakers, a BMR based loudspeaker behaves differently in listening room environments. Thanks to the BMR's consistently wider dispersion, the reverberant damping of the room will be more significant. It is helpful therefore that the room shows a consistent reverberation time, rather than a particular reverberation value. The BMR loudspeaker will also benefit from placement reasonably distant from adjacent walls.

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The Ovator S-600 Bass Driver

Although the bass driver looks conventional from the outside, there is are numerous technical subtleties hidden within. As with the BMR motor, the 200mm bass driver motor is the result of thorough finite element analysis.

The pole piece is designed to achieve very high linearity of driving force (see Fig. 11) and together with the spider's linear suspension characteristics this guaranties extremely low distortions at low frequencies.

The design also features two demodulation rings, which reduce impedance variations while the voice coil is moving and also secure low distortion figures originating from demagnetisation of metal parts due to the voice coils travelling AC-field. The large ventilation hole in the centre of the pole piece avoids air compression underneath the dust-cap and causing mechanical losses.

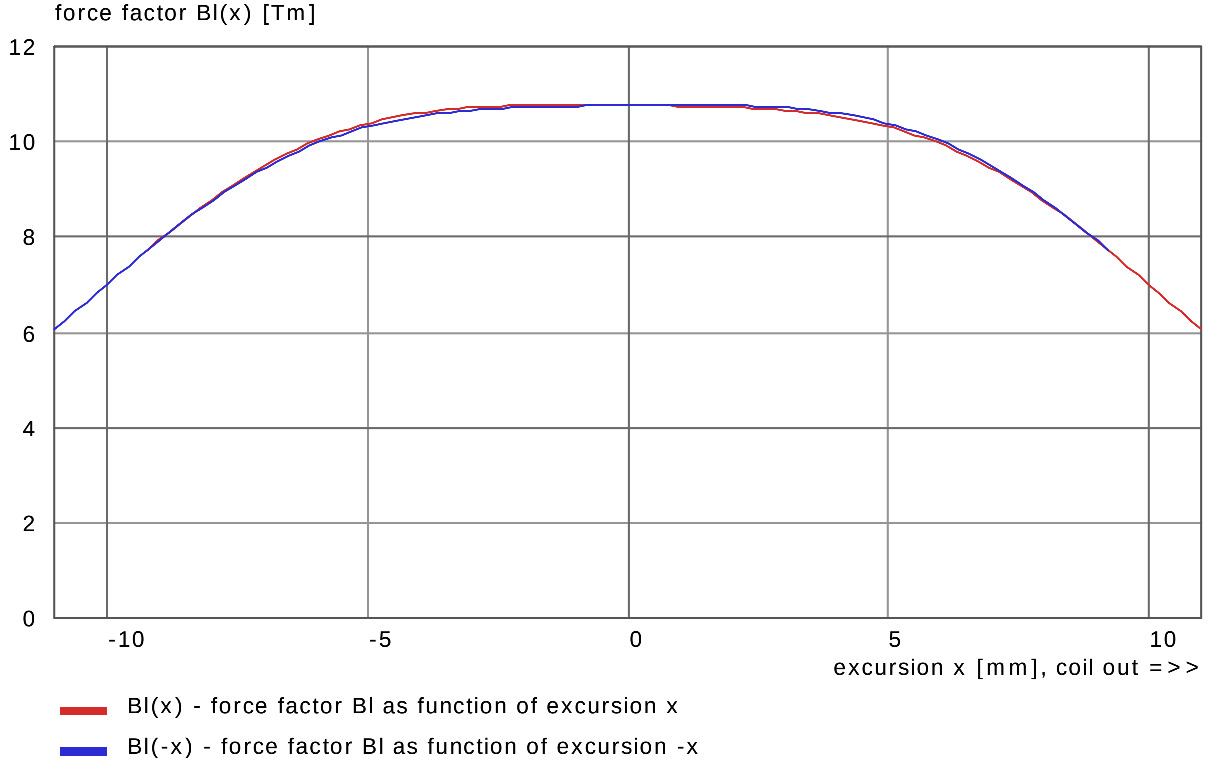

Fig. 11 Measured force factor Bl as function of excursion x and –x (Bl(-x) illustrates the symmetry of the generated force).

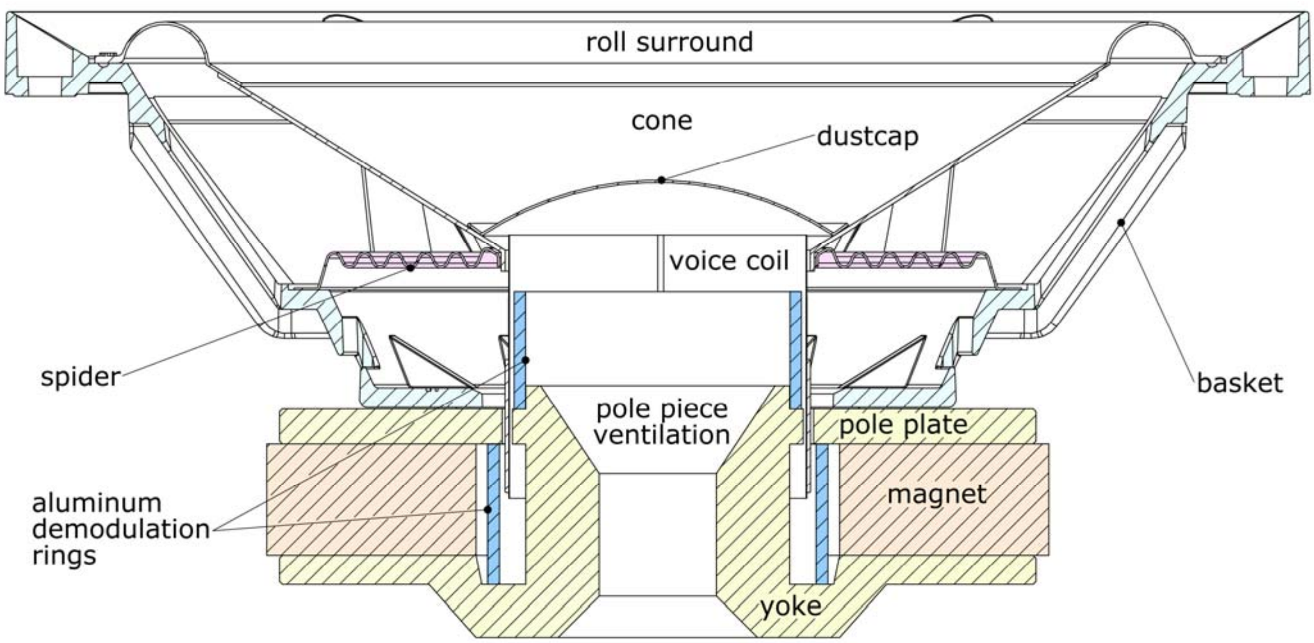

Fig. 12 Cross-section view of 8" Naim woofer.

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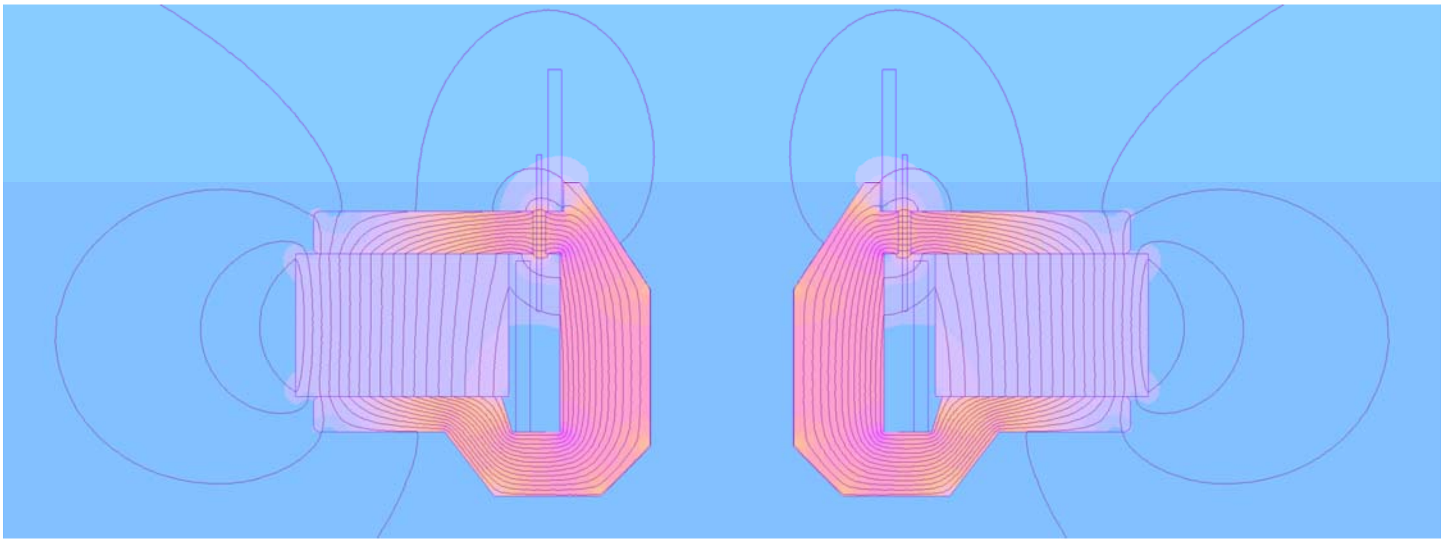

Fig. 13 Flux density plot of 8” Naim woofer.

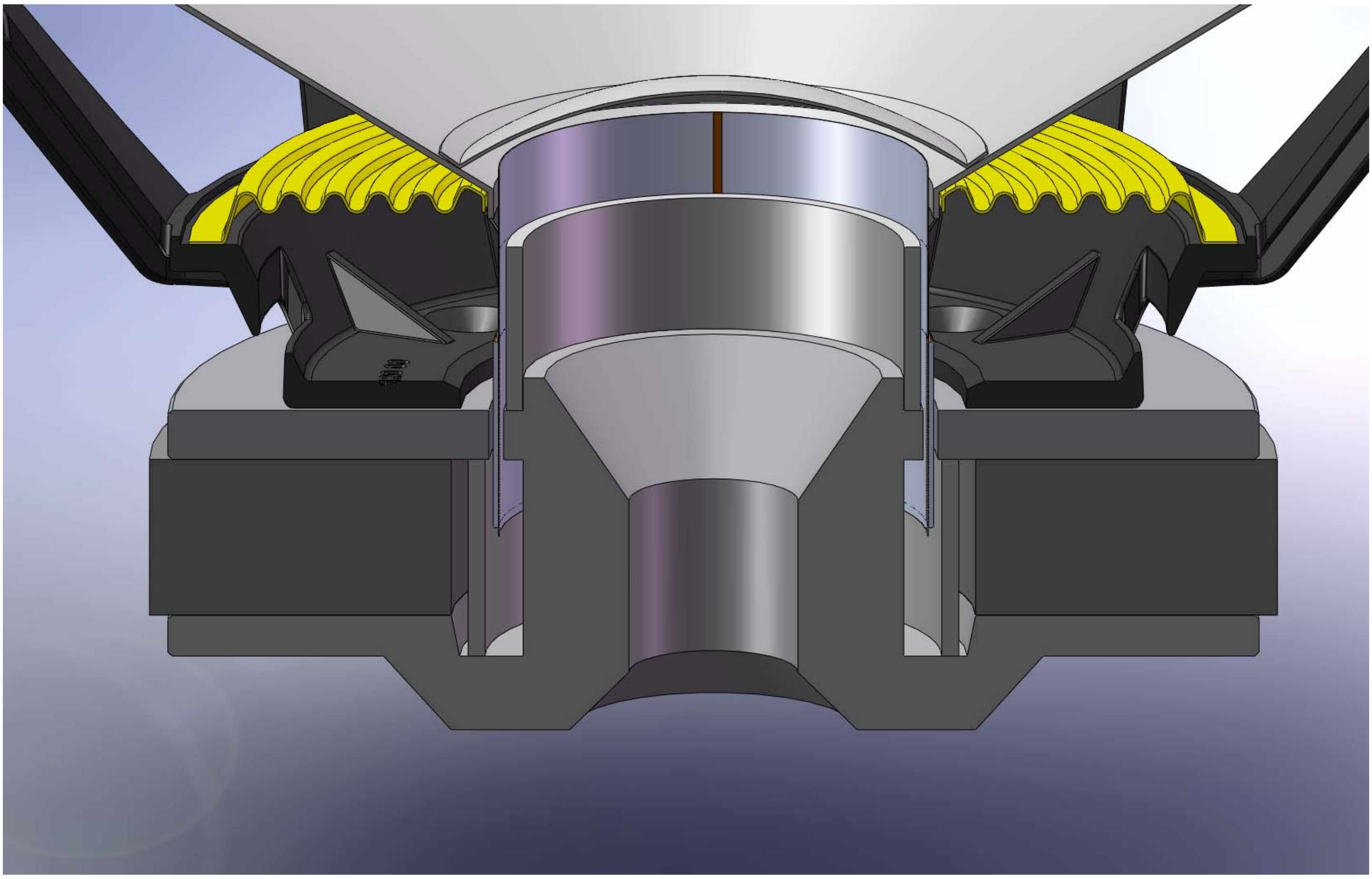

Fig. 14 Coss-section of Ovator S-600 Bass Driver

The bass driver cone is long-fibre paper item with medium stiffness and was chosen to match the sound character of the BMR. Its rubber surround applies only light damping in order to avoid hysteresis effects in the suspension system and first break up mode is controlled by the shape of cone and surround instead of through the use of mechanical damping which would compromise the driver’s dynamic behaviour.

Together with the closed box cabinet, the drivers achieves the target alignment of around 38 Hz with a total Q of slightly below 0.6 to guarantee the best compromise between low end extension and impulse behaviour.