The Mangerbox

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1. OVERVIEW

The aim of the Mangerbox project was to build a point-source loudspeaker using a high-quality wide-range driver in order to achieve time coherent sound reproduction. In contrast to many other wide-range driver designs, this loudspeaker should achieve a flat frequency response and a high WAF[1].

The Mangerbox is implemented as a FAST[2] system. The crossover frequency between the full-range driver and the woofer is chosen such that the wave length of the crossover frequency is much larger than the distance between the two drivers in order to ensure the point-source behaviour throughout the entire frequency band. Both drivers operate in small closed-box chambers. Active DSP[3] filters are used to obtain a flat frequency response. The woofer low-frequency response is equalised using a Linkwitz pole-zero transform.

This document describes the design and the performance of the Mangerbox. All measurements shown were made using MATAA [1] following standard methods [2].

2. DRIVERS

The full-range driver used in the Mangerbox is the unique and famous Manger Schallwandler (MSW, type WO-5). Unlike conventional loudspeaker drivers with rigid membranes, the MSW is a bending-wave transducer. The movement of the voice coil at the center of the highly flexible membrane induces a wave that travels radially across the membrane towards the edge of the membrane, similar to surface waves caused throwing a stone into a pond. The Manger MSW has a flat frequency response from about 300 Hz and up, which makes it highly suitable for a high-quality FAST loudspeaker. At lower frequencies, the wave length exceeds the limit for bending-wave operation of the MSW membrane, which results in conventional piston-like membrane movement.

The woofer used in the Mangerbox is a 20 cm Visaton TIW 200 XS unit. This woofer features a very rigid membrane and a very high voice-coil excursion limit for linear-drive operation. These features provide the mechanical basis for a clean and deep bass.

3. ENCLOSURE

The Mangerbox enclosure is designed as a relatively small, unobtrusive floor-standing box (Fig. 1). The enclosure is just wide enough to mount the MSW on the front. In addition, the woofer is placed on the side of the box. This has no negative acoustical effects due to the uniform directivity of the sound emission at low frequencies. The upper part of the front panel where the MSW is mounted is slightly slanted. The MSW and the woofer operate in separate closed-box chambers.

The MSW chamber with a volume of 7.8 L is acoustically dampened using Bofoam layers covering the inner surfaces of the chamber (dark grey in Fig. 1) and a wedge made of "Manger Zähschaum" (grey) and acoustic foam (light grey). This dampening minimises sound reflections from the rear wall that would be emitted through the MSW membrane and interfere with sound reproduction.

The impedance measurements (Fig. 2) show that the resonance frequency of the MSW increases from about 83 Hz in free air to 120 Hz in the Mangerbox. Also, the use of "Manger Zähschaum" and the acoustic foam in the MSW chamber results in a slight dampening of the MSW impedance peak at the resonance frequency. The smaller impedance peaks at 276 Hz, 469 Hz, 713 Hz, and 1500 Hz reflect resonances within the MSW bending-wave membrane, which are not affected by the Mangerbox chamber or dampening material.

The 23 L woofer chamber is dampened only using two layers of acoustic foam installed at the bottom of the box in order to dampen the 290 Hz resonance resulting from a standing wave developing along the vertical axis of the woofer chamber (Fig. 3, small impedance peak at 290 Hz). In addition, the enclosure is internally reinforced using braces in order to minimise vibration of the box. The in-box woofer impedance curve indicates a resonance frequency of 52 Hz and $Q = 1.61$.

[1] Woman acceptance factor
[2] Full range and subwoofer technology
[3] Digital signal processing

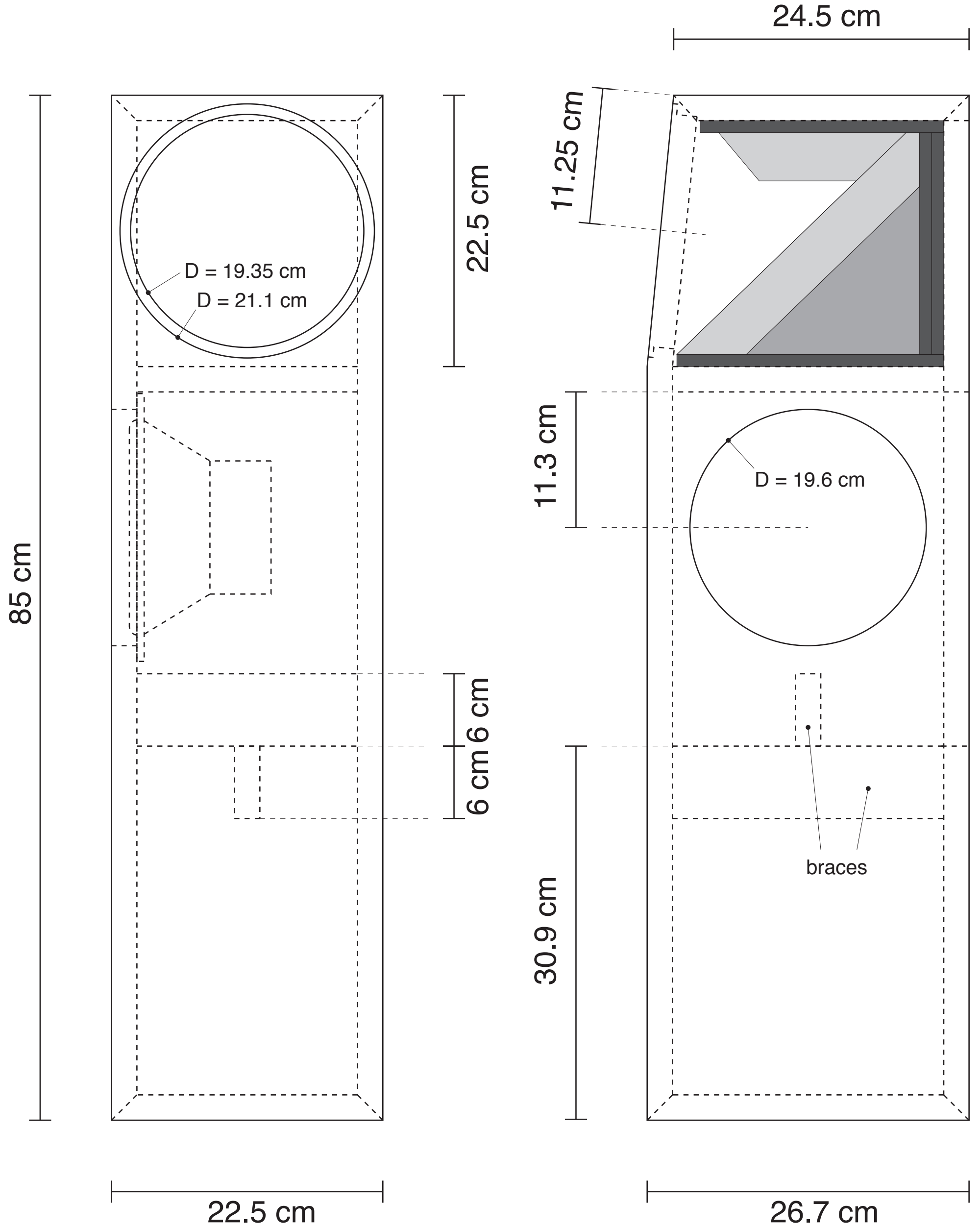

Figure 1: Drawing of the Mangerbox enclosure (see text for dampening materials in MSW chamber).

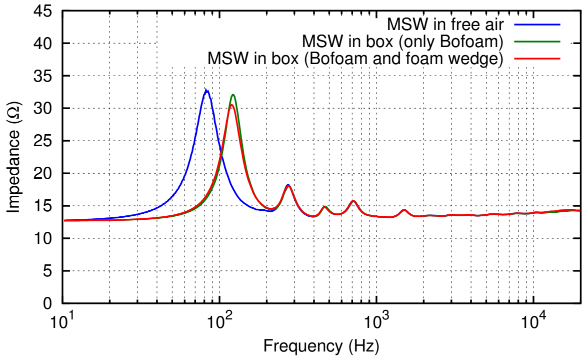

Figure 2: Impedance of the MSW in free air and in the box (with different dampening options, see Fig. 1 and text).

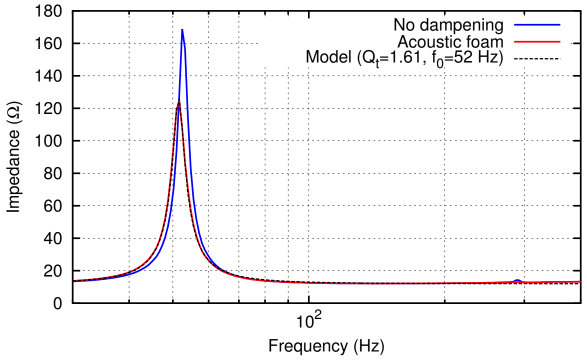

Figure 3: Impedance of the woofer installed in the box, showing the dampening effect of the two layers of acoustic foam installed at the bottom of the box. The model curve corresponds to a closed-box system with resonance frequency f_0 = 52 Hz and Q_t = 1.61.

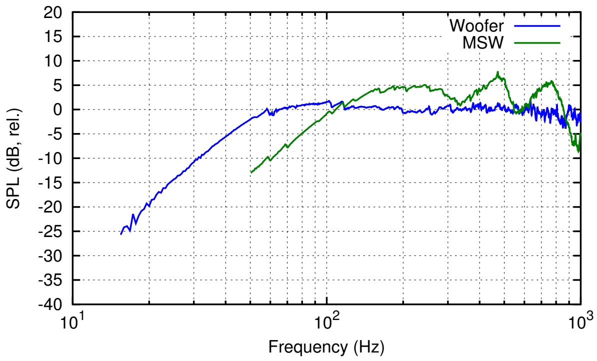

Figure 4: Near-field SPL frequency response of the MSW and the woofer (without crossover filters).

4. CROSSOVER FILTERS

The crossover filter between the MSW and the woofer should result in an acoustical crossover frequency of about 300 Hz. To minimise interference of the sound emitted by the MSW and the woofer in the crossover-frequency range, steep filter slopes are necessary. This also helps to reduce distortion resulting from large excursions of the MSW voice-coil that may occur at low frequencies. Also, the MSW frequency response should be improved by equalising the ripples inherent to the MSW driver, and the woofer response requires a Linkwitz transform to equalise the high *Q* and resonance frequency resulting from the small volume of the woofer chamber. Finally, the sound emitted by the MSW needs to be delayed to compensate the offset of the woofer relative to front baffle. To meet these requirements, elaborate active filters are required. I therefore use active DSP filter modules that are conveniently built into the power amplifiers with the Mangerbox [4] (HiFiAkademie dspModules and PowerAmps).

Fig. 4 shows the near-field SPL responses of the MSW and the woofer in the Mangerbox without any filters and equalisers. The low-frequency SPL response of the MSW increases with a slope of 12 dB/oct up to about 140 Hz and then becomes flat. The SPL variation observed in the near-field measurement at 300 Hz and higher frequencies is most likely a result of the inhomogeneous sound emission across the bending wave membrane. The woofer SPL response also shows a 12 dB/oct slope at low frequencies, which is typical for closed-box systems. For frequencies higher than the resonance frequency of the woofer/box system (52 Hz), the frequency response is rather flat.

The near-field measurements of the MSW and the woofer do not show any unexpected behaviour in the low-frequency range up to intended crossover point (approximately 300 Hz) and beyond. The design of the high-pass filter for the MSW as well as the low-pass filter the the Linkwitz transform for bass equalisation of the woofer was therefore straightforward. The corresponding filter settings were optimised by iteratively modifying the corresponding DSP settings and measuring the near-field responses of the MSW and the woofer (second-order MSW high pass filter with f_0 = 400 Hz and Q = 0.5, second-order woofer low-pass filter with f_0 = 268 Hz and Q = 0.6). The Linkwitz transform used with the woofer equalises the woofer/box resonance (Fig. 3) to a flat woofer SPL response down to a –3 dB point of 30 Hz (Q = 0.707). In addition, the DSPs are set to delay the MSW signal by 0.41 ms relative to the woofer, and the woofer signal is inverted and amplified by 3.5 dB relative to the MSW signal. Finally, the DSPs were set to block resonances of the Visaton TIW 200 XS woofer at 575 Hz and 2390 Hz.

Table 1: DSP settings for MSW filter

Equalisers		
f_0 (Hz)	Q	attenuation (dB)
700	1.65	0.6
918	3.1	2.2
1375	0.81	-0.5
1440	1.1	-4.4
1845	2	5.1
2115	3.25	-3.3
2435	6.7	-2.6
3275	3.7	-2.6
5000	9.8	-1.6
Shelving filters		
f_0 (Hz)	Q	attenuation (dB)
4180	0.5	-3.0
2165	0.5	-1.3

5. RESULT

Fig. 5 shows the far-field SPL response of the MSW in the Mangerbox without any filters and equalisers. There are numerous dips and peaks. The amplitudes and center-frequencies of most of these dips and peaks depends strongly on the horizontal position of the microphone. This indicates that most of these features result from interferences of the sound waves emitted from different areas of the (rather large) MSW membrane or from sound reflections at the edges of the cabinet. These narrow-band lobing effects must not be compensated using the DSP filters, because the sound field registered by the listener is a superposition of the direct sound emitted from the MSW and the sound reflected at various angles from the room. However, the dip at approximately 700 Hz and the peaks at approximately 1.5 kHz are observed consistently independent of the microphone position, and impedance maxima are observed at the same frequencies (Fig. 2). These two features therefore seem to be inherent to the MSW driver. A third SPL peak is observed at 3.2 kHz in Fig. 5 at all angles up to 60°. This third peaks is also an MSW artifact, which is equalised using an active filter in the Manger Studio Monitor speakers [3]. All three features are equalised in the Mangerbox DSP filters. The exact DSP equaliser settings (Tab. 1) were determined empirically by iteratively modifying the settings and measuring the SPL responses of the MSW in the Mangerbox at different microphone angles.

Fig. 6 shows the transfer functions of the DSP filters used with the MSW and the woofer in the Mangerbox. The implementation of such complex transfer functions is not practical with classical analogue circuitry, whereas the use of DSPs is straight forward. The resulting SPL frequency response of the Mangerbox (Fig. 7) is generally very flat with the exception of the variable wiggles resulting from horizontal lobing. These wiggles hardly affect the in-room sound balance perceived by the listener due to the integration of

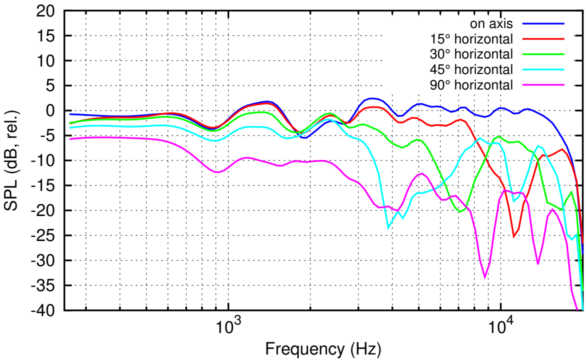

Figure 5: Anechoic frequency response of the MSW in the Mangerbox without crossover filters measured at 1 m distance from the front baffle and at different horizontal offset positions (angles relative to the MSW axis).

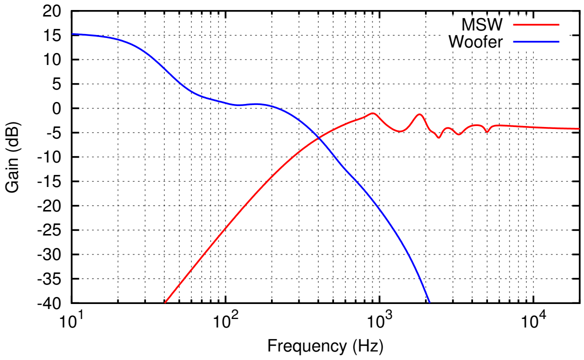

Figure 6: Transfer functions of the DSP filters use for the MSW and the woofer.

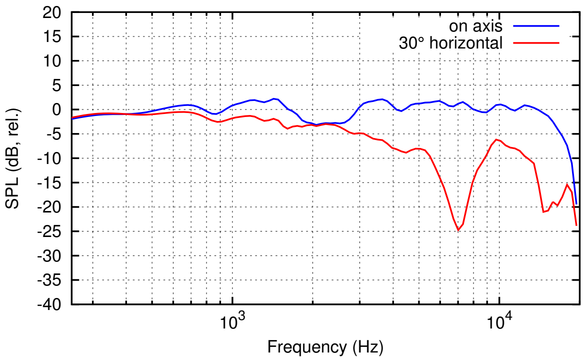

Figure 7: SPL frequency response of the Mangerbox at 1 m distance from the front baffle (on axis and 30° horizontal offset).

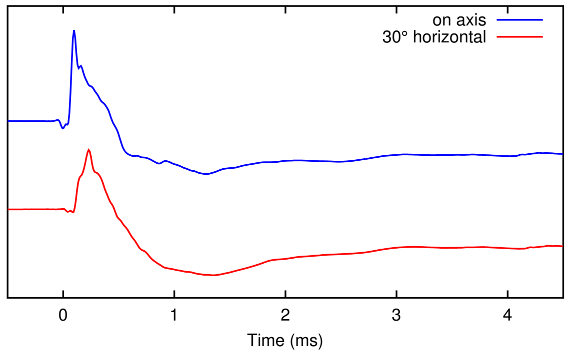

Figure 8: Step response of the Mangerbox at 1 m distance from the front baffle (on axis and 30° horizontal offset).

the direct sound from the MSW and room reflections from various angles.

The Mangerbox SPL response is strikingly similar to that of the Nonagon loudspeaker [5], which also uses an MSW with DSP filters. In contrast to the Nonagon loudspeaker, however, the Mangerbox reproduces sound in a perfectly time-coherent way as indicated by the step response (Fig. 8), which is very close to the theoretical ideal. Indeed, listening to music with the Mangerbox is a bit like listening through high-quality headphones, except that the musical stage is reproduced in the listening room instead of in your head.

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