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A low-cost, lightweight, flat and very-high-efficiency loudspeaker system for low frequencies

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Abstract

The introduction of concepts such as Flat TV and 5.1 channel sound reproduction systems has led to a renewed interest in obtaining a high sound output from compact loudspeaker arrangements with a high efficiency. Compact relates here to both the volume of the cabinet into which the loudspeaker is mounted as well as the cone area of the loudspeaker. Normally, low-frequency sound reproduction with small transducers is quite inefficient. To increase the efficiency, we map the low-frequency region, say from 20 to 120 Hz, to a single tone and use a special transducer with a very high efficiency at that particular tone.

Keywords: Transducer, Bass, high-efficiency, frequency mapping, sound reproduction, loudspeaker.

Introduction

Direct-radiator loudspeakers typically have a very low efficiency [1-5], since the acoustic load on the diaphragm or cone is relatively low compared to the mechanical load. On the one hand, the efficiency is inversely proportional to the moving mass, while on the other hand it is proportional to the square of the product of the cone area and the force factor, which is determined by the magnet system and the voice coil. Furthermore, in order to get a sufficiently low resonance frequency, the moving mass must be high enough, and the cabinet volume - which acts as an air spring - must be large enough. For many consumer applications, however, the cone size should be small. In addition, the driving mechanism of a voice coil is quite inefficient in converting electrical energy into mechanical motion [4]. These conflicting conditions cannot be met with a classical loudspeaker. Low-frequency drivers (woofers) have a magnetic structure (Fig.1, right side) that is rather large, so that the typical frequency response is flat enough and the efficiency is high enough.

Figure 1: Left: the magnet system of the Bass transducer; right: a normal medium-sized bass loudspeaker (50-Euro-cent coin for size comparison).

Our solution

Our solution consists of two steps. First, we relax the requirement that the frequency response must be flat. By making the magnet considerably smaller (Fig.1, left side) a large peak in the sound pressure level (SPL) curve (Fig.2) will appear. At the resonance frequency, the efficiency can be a factor ten higher than that of a normal loudspeaker. In this case, we have at the resonance frequency of about 70 Hz a high level of almost 90 dB at an input power of 1 Watt, using only a small cabinet of 1 l volume. Since it is operating in resonance mode only, the moving mass can be enlarged, without degrading the efficiency of the system. However, due to the large and rather narrow peak, the normal operating range of the driver decreases considerably. This makes the driver not suitable for normal use. To overcome this, a second measure is applied.

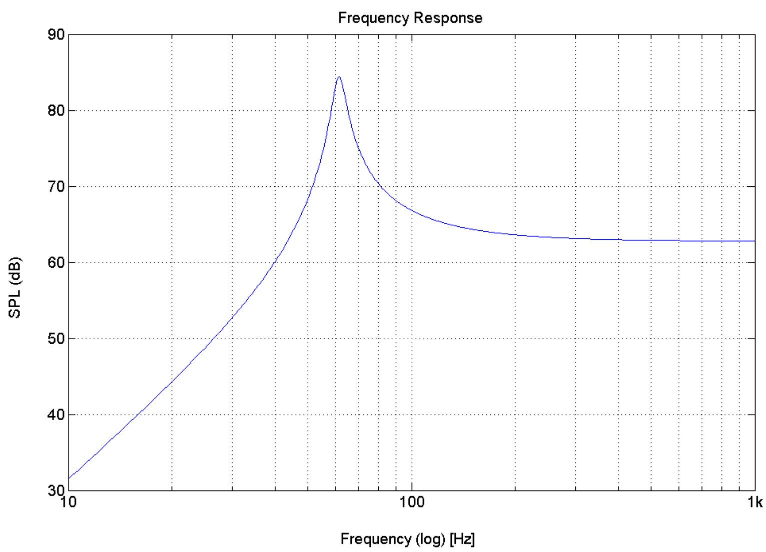

Figure 2: Response SPL vs. frequency of the Bass driver.

We map the low-frequency content of the music signal, say from 20 to 120 Hz, to a slowly amplitude modulated tone whose frequency equals the resonance frequency of the transducer, see Fig. 3.

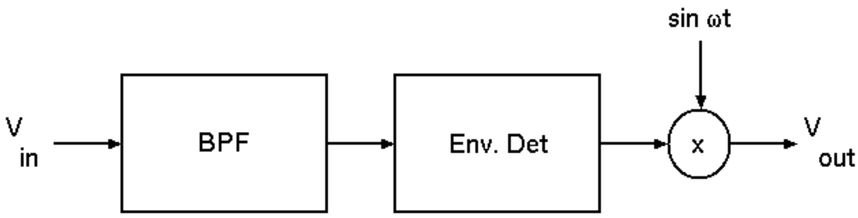

Figure 3: Frequency mapping scheme. The box labeled 'BPF' is a band pass filter (typically from 20 to 120 Hz), and 'Env. Det.' is an envelope detector, the signal V_{out} is fed (via a power amplifier) to the driver.

The modulation is chosen such that the coarse structure (the envelope) of the music signal after the mapping is the same as before the mapping [1,2,4]. Both a digital and an analog version of the required electronics have been implemented, the latter one requiring less than a dozen transistors and a few RC components. Prototypes of the new driver are shown in Figs.4-5.

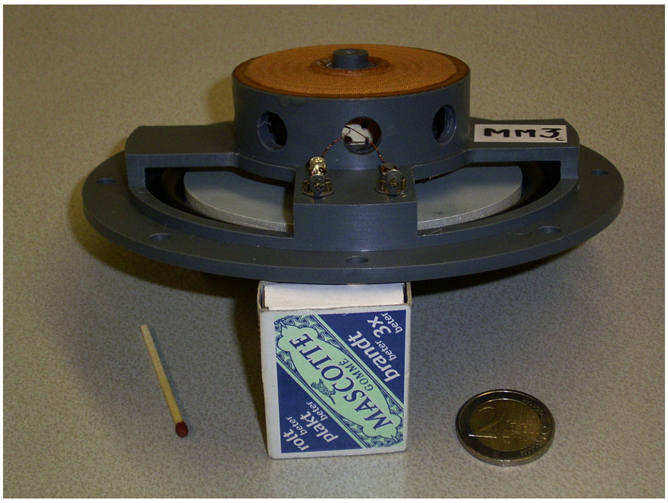

Figure 4: Prototype (MM3c) of the Bass transducer (2-Euro coin and matches for size comparison).

Listening tests

Preliminary listening tests have shown that the new system is very well appreciated. Currently listening tests are being conducted for the application in a Flat TV set.

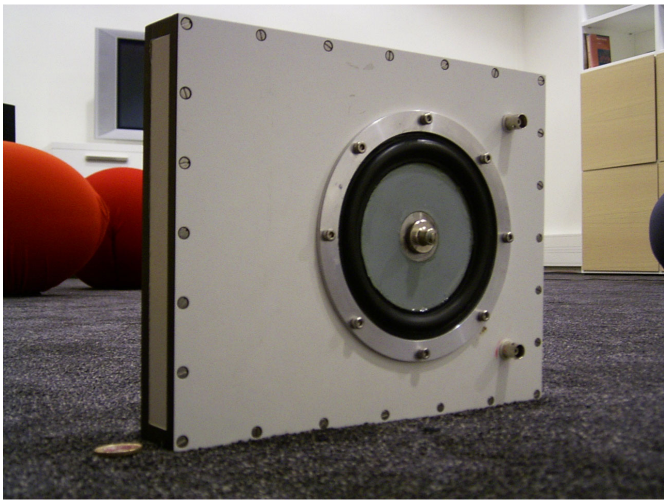

Figure 5: Prototype (MM800) of the Bass transducer in a 1 l cabinet (1-Euro coin for size comparison).

Applications

The new system is applicable to all devices requiring loudspeakers, but especially in Flat TV, 5.1 channel receivers, and small mobile audio devices.

Conclusions

A new driver has been developed, which together with some additional electronics yields a low-cost, lightweight, flat and very-high-efficiency loudspeaker system for low-frequency sound reproduction.

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