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## **APPLICATION OF MAXXBASS® PYSCHOACOUSTIC BASS EXTENSION TO SUBWOOFER DESIGN**

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### **ABSTRACT**

MaxxBass® psychoacoustic bass extension signal processing technology offers loudspeaker system engineers a new method to improve loudspeaker performance by shrinking enclosure requirements and/or improving power efficiency. Several MaxxBass optimized subwoofer have been implemented and will be compared with traditional design through quantitative measures and listening tests.

### **1 MAXXBASS CHANGES THE RULES FOR SUBWOOFER DESIGN**

Faithful reproduction of bass frequencies is the most difficult and costly goal in loudspeaker design.<sup>1</sup> The rules for bass reproduction are well known and can not be overcome. This golden rule of bass reproduction is simply tradeoff in low (bass frequency range), loud (sound pressure level) and size (speaker and enclosure volume). If one desires to reduce the size of speaker they need to give up low and/or loud. New transducer materials, amplifiers designs and enclosure configurations keep bending this rule as far as possible, but the in reality we are eking out every smaller incremental improvements. If only we could change the laws of physics, just a little....

This, in fact, is exactly what MaxxBass does. It changes the laws of physics by a nifty little slight of hand, or to mangle a metaphor: a “slight of ear”. It lets us move that low frequency target or the “low” in the golden rule, up an octave or more. Instead of targeting a low cut off of 40Hz in typical subwoofer design, we can target 80 to 100Hz and let MaxxBass fill in the missing bass.

What this means to the designer is really phenomenal. Speakers, boxes and amplifiers can all get smaller. The engineering doesn't change, just the targets. This opens up a whole new category of speakers- call them mini-subwoofers or MiniWoofers®. These MiniWoofers can create the sense of low bass in a huge number of applications that were not practical before MaxxBass.

- Multimedia subs that can fit *under* a monitor.
- Automotive subs that can fit under a car seat.
- Tiny plasma TV's subs that hang on the wall.
- 2.1 bookshelf systems with the sub actually on the bookshelf.
- Inwall Subs that don't require exotic bracing or cabinets.

MaxxBass can also be applied to full range speakers to improve their bass extension without changing the higher frequency response. It will create the sense of low bass extension without the requirement of large speakers, cabinets and amplifiers.

## **2 PHENOMENON OF MISSING FUNDAMENTAL**

Human love of bass has driven a search for methods of producing louder and lower bass sounds. Our fondness of bass dates back to prehistoric drums made from sticks and stretched animal skins and continues with modern electric bass guitars. Drums, horns, woodwinds and string instruments all have versions designed primarily for playing bass frequencies. This drive to generate louder and lower bass frequencies may have reached a peak with pipe organs installed in cathedrals during the Middle Ages. These large pipe organs generated low pedal tones using pipes up to forty feet long to generate really low frequencies that helped draw crowds of people to these church services to feel the bass as well as hear the spiritual message. These pedal tones from large pipe organs shake our bodies similar modern car audio systems and home theater subwoofers.

In the early 1700s some composers of written music, specifically for pipe organ, found that they could “trick: the listener into hearing low bass tones that weren't really there if they played a certain combination of notes that were higher than the low tone or “fundamental” that they wanted to be heard. For example, if they wanted the listener to hear a low C then they could play a C an octave higher and a G above that, and the low C would magically appear in the listener' head.<sup>2</sup>

The Phenomenon of the Missing Fundamental has also been studied and proven by many distinguished audio scientists such as Helmholtz, who discovered how vented port and vents operate. The perceived pitch of a combination of tones spaced equally in frequency is usually not that of the mean frequency, but rather that of the constant difference frequency.<sup>3</sup> The constant difference frequency is the missing fundamental.

## **3 MAXXBASS**

Meir Shashoua, the CTO of Waves, developed a theory on how the Phenomenon of the Missing Fundamental could be applied to loudspeaker reproduction limitations. Waves, the leader in audio signal processing 'plug-ins' tools for the professional audio market, leveraged its world leadership psychoacoustics to improve and sharpen this

psychoacoustic effect. This technology, called MaxxBass was patented (U.S. Patent #5,930,373).

Waves MaxxBass plug-in utilize has become a standard tool over the past few years in creation of much of the world's most popular music. This software tool is used by mixing and mastering engineers used to improve bass punch on bass limited systems. This is important for popular music may be played on everything from dance floors with subwoofer arrays to small portable systems with severely limited bass capability. An example of the music mixed with this MaxxBass technology is "Lady Marmalade" by Christina Aguilera.

The MaxxBass is even more effective when implemented directly in consumer audio reproduction systems, since the MaxxBass can be tuned to the specific loudspeaker parameters improving performance on any audio bass content. This is now possible due to a cost-effective MX3000AS ASIC (Application Specific Integrated Circuit) as well as software algorithm licensing on audio DSPs from several manufacturers.

Another significant advantage of implementing MaxxBass in consumer audio equipment is that this solution, unlike the professional audio mixing tool, includes a high pass filter (HPF) removing the original bass frequencies that can not be reproduced by the loudspeaker. These frequencies are no longer needed since MaxxBass reproduces these through psychoacoustics. The HPF eliminates damaging speaker excursion, unnecessary power consumption and undesirable intermodulation distortion in the loudspeaker.

#### **4 APPLICATIONS**

Boosting the low-frequency performance of a speaker by 1-1.5 octaves requires both increased headroom in the amplifier and increased excursion in the driver, plus extra BI to maintain control at high excursion, all of which involve substantially more cost than implementing MaxxBass.<sup>4</sup> MaxxBass is a powerful and cost-effective technology for audio system designers to improve bass response. It has widespread benefits across audio applications including automotive, home audio, multimedia, television, portable and personal audio.

On loudspeakers with good bass response such as subwoofers, MaxxBass can be used to substantially reduce size and cost by redesigning the speaker system. MaxxBass guarantees maximal system efficiency with minimum compromise. MaxxBass allows a much higher target  $f_3$  which results in

- A much lighter moving mass for the driver
- A substantially more compact enclosure
- Substantially higher SPL or reduced amplifier requirements.

## 5 SUBWOOFER DESIGN WITH MAXXBASS

### 5.1 REFERENCE 8" SUBWOOFER DESIGN

Let's compare a traditional subwoofer design to a MaxxBass optimized design, so that realistic comparisons can be performed. First let's consider the traditional design as a reference.

When a designer starts a new subwoofer design, they typically (if they are lucky) get a marketing goal that goes something like this:

- Cabinet size: less than .4 cubic feet
- Speaker size: 8" (cheap – paper cone)
- Box type: Sealed or vented, smooth response, not boomy
- F3: 50 Hz.
- Peak acoustic output: >105 dB @ 1 meter
- Maximum amplifier size: 50 Watts

With these guidelines a proficient designer can come up with a woofer design that will meet these criteria for the lowest cost. With *ReverseSpeaD* software this task is actually fast and easy.

1. We know the cone size and material so we can estimate the mass as 18 grams.
2. We know the power handling will be around 50 watts so we can set the coil diameter at 1.5" and with a starting Xmax of 8mm, using *SpeaD*, we can estimate the coil mass as 28 grams.
3. Adding in another 6 grams for glue and a small cap, the total Mmd will be about 52 grams
4. With this information and the marketing data we can begin to enter values in *ReverseSpeaD*.

The 8" target subwoofer in the Appendix show the targets and *SpeaD* design for a speaker that meets these design goals.

### 5.2 MAXXBASS 8" SUBWOOFER DESIGN

MaxxBass can convince the listener that they are hearing a bass extension of 1-1/2 octaves. In practice though, its not a bad idea to build a little safety into the design so assuming a 1 octave extension is not a bad idea. This means the that target F3 of the system is not 50 Hz., it is 100 Hz.! This changes the speaker design completely.

The options for MaxxBass designs are smaller boxes, smaller less expensive speakers and smaller amplifier requirements. Of course the ideal will probably be a compromise of all of these.

Example 1 – staying with an 8" speaker, 50 watt amplifier, same magnet parts and optimizing for cabinet size.

The cone mass won't change however the voice coil requirement will go down substantially. Using *SpeaD* and *ReverseSpeaD*, you can optimize a design fairly quickly.

The results show a speaker with a very short Xmax will produce the same design goals in a box that is about ¼ the size of the conventional design.

The Example 1 design in the Appendix shows both the *ReverseSpeaD* targets and *SpeaD* design for MaxxBass Optimized Subwoofer

### 5.3 MAXXBASS 6.5” SUBWOOFER DESIGN

If the designer is able to convince marketing that they can get the same results with MaxxBass and a 6.5” woofer, the final product becomes very different and much, much less expensive.

The Example 2 section of the Appendix provides the *ReverseSpeaD* targets and *SpeaD* design for the MaxxBass 6.5” Optimized Subwoofer.

*These changes represent a substantial cost savings over the original design on the order of 50% to 70%.*

A comparison of the three similar sounding subwoofers is shown below.

Reference 8”	MaxxBass 8”	MaxxBass 6.5”
8” woofer	8” woofer	6.5” woofer
18.7 Oz magnet	18.7 Oz magnet	12.8 Oz magnet
8mm plates	8mm plates	6mm plates
1.5” coil	1.5” coil	1” coil
50 watt amplifier	35 watt amplifier	35 watt amplifier
.4 cubic foot box	.1 cubic foot box	.1 cubic foot box

### 5.4 OTHER CONSIDERATIONS

The appendix section contains an example of a MaxxBass application using the transducer design tools *SpeaD* and *ReverseSpeaD*. They make it very easy to play “what if” with MaxxBass designs, and can greatly reduce the development time for MaxxBass speakers.

There are some additional considerations that need to be followed when designing a MaxxBass speaker. The first is that although low bass is non directional, the harmonics that create the sense of bass with MaxxBass are. The critical MaxxBass output range will extend to the 300 to 500 Hz. This means that you need to consider the directionality or aim of your bass. For example a down firing MaxxBass sub will not be as effective as a front firing.

## 6.0 CONCLUSIONS

MaxxBass enables loudspeaker designs to achieve dramatic size, power and cost reductions in subwoofers and full range loudspeaker systems. Applying MaxxBass to subwoofer design allows the low frequency roll-off to be increased by an octave or more improving the efficiency of the loudspeaker system.

MaxxBass does not alter the physics of bass reproduction, but offers an opportunity to dramatically improve loudspeaker bass performance through consideration of proven auditory perception to the system design. This will change the rules for loudspeaker bass reproduction and is analogous to the established considerations of visual perception in display and television design.

## 7.0 RECOMMENDED CONSULTANTS FOR FURTHER DEVELOPMENT

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