Beyond physics for superior sound

Philips Research is mixing innovative loudspeaker technology with physics, digital signal processing and just a little audio 'mind magic' to bring high-fidelity sound reproduction to tomorrow's products.

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Photography: Gerhard van Roon, Michel Klop

The human ear is one of Mother Nature's most amazing creations. It can detect sounds from the faintest whisper to the loudest thunderclap, and the slightest of tuning errors in a musical note, rhythm or score. All this is achieved by receiving and converting sound waves into electrical impulses with such precision that the brain can interpret and distinguish an almost infinite variety of sounds.

For scientists and engineers tasked with improving sound reproduction using modern electronics, the human ear provides a salutary lesson in perfection; and one that never lies. Products that reproduce perfect frequencies and wide dynamic ranges according to the artificial ear of a lab microphone in a room engineered to give perfect acoustic response, can sound awful to the human version in a cluttered living room with dubious acoustics. This is one of the reasons why Philips Research's Digital Signal Processing (DSP) Group has a specialized team of six researchers – known as the Acoustics & Sound Reproduction Group – who utilize knowledge of the highly refined sensor that is the human ear: how it works, its capabilities and its limitations. The reference point for all their research is not a frequency response spectrum on a measurement instrument, but feedback from a human listener. "We have found, for example, that you don't need exceptionally high resolution for spatial reproduction because the human ear is not very sensitive when it comes to distinguishing between sources that are less than a few degrees apart," explains Prof. Ronald Aarts, Research Fellow and a veteran Philips Researcher who specializes in sound reproduction improvements and leads the dedicated group. "By understanding the capabilities of the ear,we can set boundary conditions within a technical design specification that allow us to create an audio system that sounds incredible to consumers."

Over the last decade, the group has made remarkable progress and spawned hundreds of patents (over a hundred filings in the last five years alone), authored dozens of papers, and created several inventions that have been successfully commercialized by Philips' Consumer Electronics product division. But as impressive as inventions such as Incredible Sound, UltraBass and Two-to-Five may be, they are merely the early fruits of a project with a much bolder mission "to provide the listener with the best sound at any time or position in space". It's an ambitious undertaking, demanding the development of 21st century sound reproduction technologies that don't just depart from conventional audio, but also attempt to push beyond the boundaries set by the laws of physics.

Conjuring perfect sound

"Our group brings together people with expertise in loudspeaker technology, physics (particularly room acoustics), digital signal processing and psychoacoustics," says Prof. Aarts. Psychoacoustics is the psychological »

Figure 1: Aural perception experiment in an echo-free laboratory

and semantic study of how the human mind interprets sound; if you think that's moving beyond the realms of the rigorous scientific methods associated with Philips Research, you could be forgiven. But sound reproduction is not always exactly predictable and psychoacoustics is the

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'magic ingredient' that transforms the perceived quality and realism produced by next-generation audio electronics. "Psychoacoustics enables us to go beyond ordinary physics," says Prof. Aarts. "Physics does set the rules, but using our extensive knowledge of human hearing – particularly its limitations - we can go one step further and trick the ear."

It's a bit like the sleight of hand a magician uses to defeat the eye, or how red/green/blue dots and lines combine to produce color television pictures. The latest innovation from the group is a perfect example. "BaryBass is a transducer that dramatically enhances the perceived bass response of compact speakers," says Okke Ouweltjes, Research Scientist within the Acoustics & Sound Reproduction group (see sidebar 'Deep notes from shallow speakers'). Ouweltjes continues: "There are particular disadvantages with small loudspeakers commonly used for portable audio products and in flat-screen TVs where space is at premium. This rules out the use of the large conventional magnetic speaker drivers and cones needed to produce low-frequency bass sounds in the 20 to 120 Hz range. The problem is that the majority of consumers can't understand and aren't interested in hearing why small speakers don't produce deep bass - they just want a solution." "This is where psychoacoustics comes in," notes Prof. Aarts. "It tells us that the human ear finds it difficult to discriminate between low bass notes when they are reproduced against a background of other music. This means that when we map the bass range of the music into a single tone, and reproduce that with a highly sensitive transducer for that particular tone, the bass produced from small speakers during a piece of music will sound to the human ear like the deep bass that could only normally be delivered from large loudspeakers."

Home theater for dummies

Recent research in the UK revealed that a nearly half (47 per cent) of all consumers fail to set up their home theater systems correctly – often omitting a speaker – and consequently experience inferior sound. There are two main problems: incorrectly connecting the wiring and positioning the speakers in the wrong locations such that the sound reproduction 'sweet spot' doesn't coincide with the listener's position defined in the recommended set-up (see sidebar 'Targeting the sweet spot'.) "We want to solve this problem by making sure that home theater systems are dramatically easier to set up and self-correcting in the event of a wiring or speaker positioning problem," says Dr. Arno van Leest, Senior Scientist within the Acoustics & Sound Reproduction group. "For example, if the user accidentally swaps the connections to a speaker they'll lose the low frequencies. We are working on a system to detect and correct this error – reinforcing Philips Sense and Simplicity brand promise at the same time."

"And if people fail to put their home theater speakers in the recommended positions or can't due to the physical constraints of their listening room," adds Dr. Werner de Bruijn, another Senior Scientist within the Acoustics & Sound Reproduction group, "we are looking at several ways to help them. This includes

DEEP NOTES FROM SHALLOW SPEAKERS

The laws of physics dictate that coxmpact speakers with small cones are inefficient and struggle to reproduce bass notes at a high sound pressure level. The problem is that a small cone just can't vibrate with sufficient amplitude to generate adequate sound pressure. The result is a limited frequency range and shallow sound.

Measuring on a Bass loudspeaker unit.

Philips' approach is to combine a highly efficient transducer and its knowledge of psychoacoustics specifically to reproduce bass notes. The transducer is called BaryBass and couples a unique magnetic driver with a long sound port. Its high efficiency means BaryBass is small enough to fit the compact speakers typical of portable audio equipment or flat screen TVs.

The transducer's high efficiency comes at the price of a restricted frequency range. However, Philips researchers have turned this into a virtue by using the fact that the human ear is poor at discerning the difference between frequencies in the 20 Hz and 120 Hz bass frequency range, especially when combined with all the other frequencies making up a music or movie sound track. Audio electronics converts all frequencies in this range to a single frequency of 55 Hz to reproduce sound by BaryBass. The listener's experience isn't diminished by the conversion into a single frequency; on the contrary, it's enhanced by the compact speaker's ability to reproduce deep, resonant bass.

widening the sweet spot to make sure it coincides with the user's position, and tracking the user in order to move the sweet spot as they move." Automatic loudspeaker configuration is a technology capable of shifting the sweet spot from poorly positioned speakers to where the user sits. This capability is an advanced development and is about to be taken up by Philips Consumer Electronics division with a view to commercialization. This technology is far in advance of the sound level compensation systems from other companies currently on the market. "Automatic loudspeaker configuration allows the system to optimize the sound reproduction after the user has positioned the speakers to compensate for positioning errors by doing much more than just adjusting sound levels," explains Dr. de Bruijn.

"The system determines the optimal processing required for the best sound reproduction based on the respective speaker locations rather than just feeding the signal dumbly to poorly-positioned speakers." (see sidebar 'Targeting the sweet spot'.) Yet another technology for simplifying home theater set-ups being investigated by Philips are speaker arrays that 'shape' the sound in order to funnel it via the walls to the listener (see figure 2).

New York... in Amsterdam

The group's scope extends far beyond sound reproduction in audio equipment, to projects combining high-quality vision with realistic sound. DreamScreen, for instance, combines high-definition large display panels with high-fidelity sound, so that, for example, a person in an office at Philips' headquarters in Amsterdam could – if they so desired - look out of their virtual window at a Manhattan streetscape complete with blaring firetruck sirens, the squawk of a newsvendor, and the screech of a yellow taxi's tires.

In a second futuristic application, speaker arrays are being used to direct localized sound to accompany shop window video displays of goods that can be purchased in the store. "A person could ask for information about a product via an audio stream in a way such that people only a meter away, receiving information about another product, aren't disturbed," explains Dr. de Bruijn.

After a decade of research by the group, the potential applications of acoustics still appear limitless. From headphones that reproduce the ambience of a concert hall, to laser loudspeakers and acoustic cooling, Philips Research is actively responsible for some of the most radical advances occurring in 21st century audio reproduction. "Many of the things we are doing with acoustics are unique," says Prof. Aarts. "Even after two decades specializing in this discipline I'm amazed at how many exciting developments we are involved with."

Source: Philips Research Password

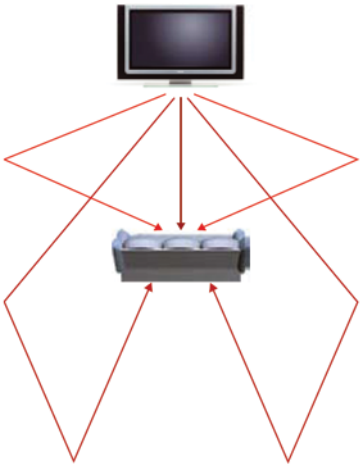

Figure 2: Loudspeaker arrays; Yet another technology for simplifying home theater set-ups being investigated by Philips are speaker arrays that 'shape' the sound in order to funnel it via the walls to the listener.

Figure 3: The use of a loudspeaker array at an interactive shopping window