

How Dirac Virtuo™ Spatializes Stereo Content for an Immersive Headphone Experience



Executive summary

Bluetooth headphone manufacturers are faced with two challenges when striving for a natural and engaging audio experience. The first is to provide spatial audio experiences to users even though most of them — manufacturers and consumers — don't belong to a spatial audio content ecosystem that supports them. The second is to attain the signature sound that their customers love, with limited budget and time to market.

Dirac Virtuo™ for Bluetooth Headphones provides a solution for Bluetooth headphone manufacturers to address these challenges. The solution turns any standard stereo content into an immersive headphone experience. The solution also digitally optimizes the acoustic performance of headphones for a clean, crisp sound while facilitating a consistent signature sound design. The solution even enables a smoother product development process and faster time to market. Manufacturers can easily integrate Dirac Virtuo™ into leading Bluetooth chipsets.

The Challenges

Sound performance

Sound quality drives consumer audio purchases. In fact, for six consecutive years, according to Qualcomm's 2021 State of Sound report, sound quality is the top purchase driver for wireless headphones.

However, it is always a challenge to achieve great sound quality and a consistent signature sound for headphones. Headphones are electro-acoustical systems with physical constraints determined by product design choices such as type, features, and size. These design choices are not always aimed at delivering the best possible sound, but they're made to provide a loveable product with a great feature set and excellent user experience. There are also some sound quality challenges that are typical for wireless headphones: a distorted soundstage due to the asymmetrical placement of components and user controls, and different ANC modes introducing undesired variability to the sound character.

These issues all get in the way of providing the highest possible sound quality for consumers. Different Bluetooth headphone chipset DSPs provide different means of improving headphone sound quality. But it is not easy to configure an effective correction solution that removes the obvious issues without over-compensating and causing new ones, while at the same time attaining that signature sound customers recognize and love. Efficient implementation is necessary for making the best use of limited resources and maximizing single-charge battery life. Sound quality is, after all, attributable also to other features, such as source content quality, Bluetooth codec, ANC, and personalization settings—all of which need to fit within the resource budget.

Immersive sound experiences

Spatial audio, which immerses listeners in a three-dimensional soundstage, is all the rage — from multichannel home theaters to wireless headphones. Qualcomm's 2021 State of Sound report found that nearly 60 percent of consumers surveyed said their purchase

of wireless earbuds would be influenced by their ability to enjoy spatial audio, a remarkable share of the mobile audio market considering the industry is just at the beginning of delivering spatial audio to wireless headphone users.

Major platforms such as Amazon and Apple have made available a limited number of music tracks produced using Dolby Atmos or Sony360 Reality Audio. But to immerse themselves in this spatial audio, consumers need headphones associated with the content provider's ecosystem.

Even if true spatial, multichannel audio were widely available for all wireless headphones, prevalent Bluetooth technology presents a bottleneck. The limited bandwidth of Bluetooth communication hinders multichannel audio transmission.

However, the vast majority of audio content in existence today — and the majority of content still being created—is actually stereo content. Bluetooth headphones are obviously capable to reproduce stereo content, but the experience is far from immersive.

Summary

If sound quality is so important to a buying decision, and if today's wireless headphones are limited in their ability to deliver spatial audio experiences — by closed ecosystems and bandwidth limitations — then a new solution is required.



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The Solution

Dirac Virtuo™ is a digital spatial audio solution that delivers high-quality, spatial audio experiences to headphone users with any standard stereo content. With a small DSP footprint, Dirac Virtuo™ can be easily integrated into market-leading Bluetooth chipsets.

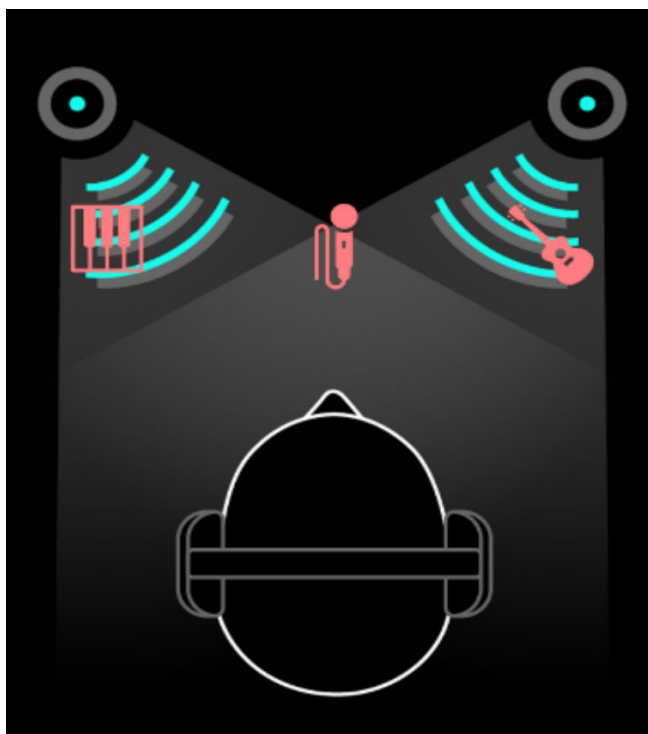
Spectral correction for maximized sound performance

The solution uses a high-resolution magnitude response correction technology to remove unintended resonances or colorations caused by the design of the headphones themselves and their components. In this way, Dirac Virtuo™ helps keep manufacturers' costs low while achieving the superior sound performance of more expensive hardware, resulting in more transparent, balanced sound with controlled bass and richer details.

With a customizable target curve, Dirac Virtuo™ makes it possible to precisely adjust for consistency and symmetry across all form factors and ANC modes. This results in a greater sound experience in all situations - not to mention a smoother product development project and faster time to market.

Spatial correction to spatialize standard stereo content

Dirac Virtuo™ uses a high-resolution binaural room impulse response technology to bring out the spatial cues that already exist in stereo recordings, recreating the listening experience originally intended by the artist. With the spatial correction of Dirac Virtuo™, sound seemingly comes from a pair of premium stereo speakers in front of the listener, rather than from inside their head, creating an externalized soundstage. No spatial audio content is required.



Spatialized stereo sound

For wireless headphone users, this means:

- A spatial audio experience from any standard stereo content
- Better, more balanced sound quality with richer detail
- A more accurate stereo soundstage than regular headphones can deliver
- A more comfortable user experience when headphones sound like premium stereo speakers

How it Works

Dirac Virtuo™ spatial audio solution has been developed and built based on a fundamental understanding of what a good sound experience should be, according to Dirac.

A good sound experience

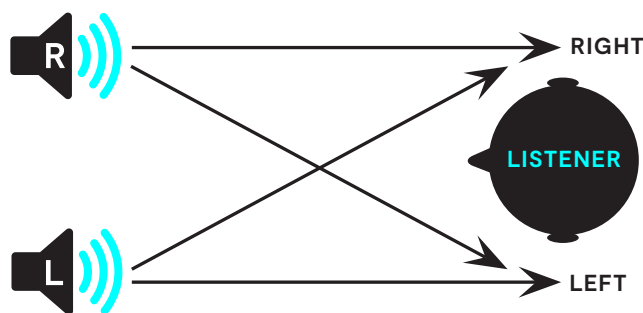
Dirac's definition of good sound is that the playback equipment should be transparent so that content can be truthfully delivered. The user experience, as intended by the creator, should not be influenced by the playback equipment.

What one needs to keep in mind then is that the content has been verified by its producer with some sort of playback equipment, which will then also be the equipment with which the content is most truly consumed. Traditionally, music is produced with stereo loudspeakers as reference, including a room, with headphones as an optional endpoint where it must sound acceptable too.

Headphones are different from loudspeakers

When music is played in a room, sound from the left and right speaker interacts with the room and arrives at the listener's ears at different times. Crosstalk is important for creating a sense of distance and direction in the soundstage. A content creator, for example, might pan a sound from one channel to the other, which comes off naturally when heard through speakers, but not in headphones.

Sound is also spectrally influenced, not only by the low-frequency resonances from the walls, floor, and ceiling in the room, but also by the listener's head and outer ear. However, none of this happens naturally with headphones, which sit directly in (or on) the listener's ears, depriving them of the natural room gain and speaker crosstalk.



The crosstalk from speakers is missing in headphones

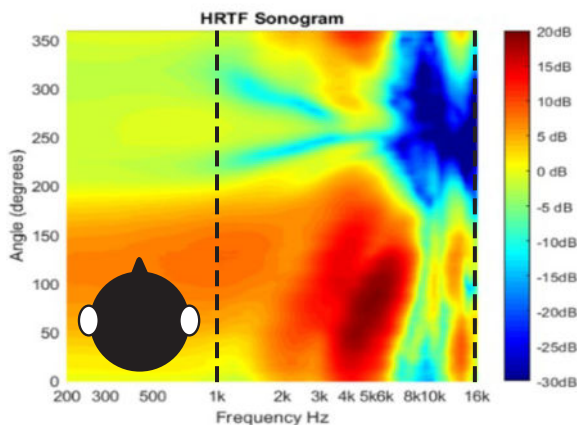
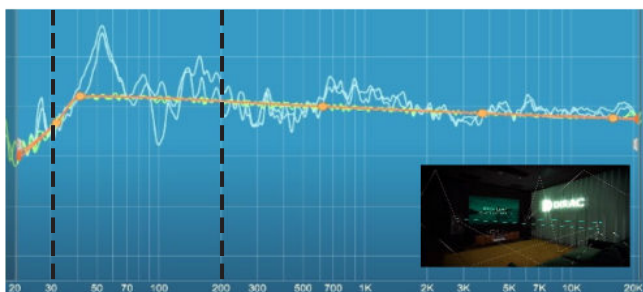
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The Dirac approach: speaker-in-a-room reference

Based on Dirac's definition of a good sound experience, the company's approach to optimizing headphone sound is to recover the intended experience from stereo content, namely the speaker-in-a-room reference. In Dirac Virtuio™, this is achieved by combining spectral and spatial headphone correction.

Spatially, this means restoring the stereo soundstage by gently adding the crosstalk that a pair of speakers in a room would have delivered. Spectrally, it means correcting the headphones' magnitude response to remove unwanted resonances while ensuring that room gain and head and pinna colorations are compensated for to simulate a natural speaker listening experience.



Room gain <200 Hz + head and pinna coloration >1 kHz

Spectral correction

The goal with spectral correction is to establish a transparent audio channel for effortless delivery of the intended experience from the artist to the user. To reach this goal, Dirac uses patented magnitude response correction technology and a semi-automatic measurement-based filter design methodology to correct headphones based on reliable measurement of the headphone acoustic characteristics. The methodology for headphone spectral correction is described in our white paper "Speaker optimization for Bluetooth headphones".

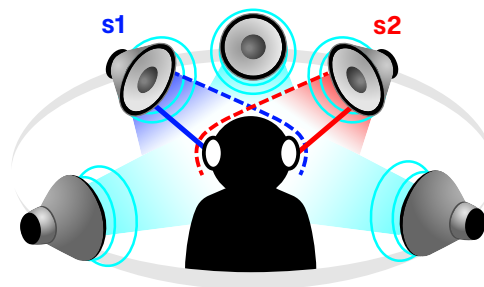
Spatial correction

Dirac Virtuio™ uses a high-resolution binaural room impulse response (BRIR) technology to restore speaker crosstalk and correct the stereo

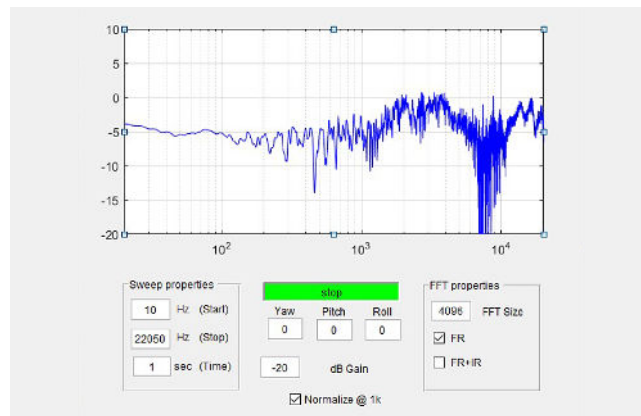
soundstage. In this way, Dirac Virtuio™ brings out the spatial cues that already exist in stereo recordings, recreating the listening experience originally intended by the artist.

BRIR acquisition

Spatial correction in Dirac Virtuio™ is based on BRIR measurements in various acoustical spaces, from home living rooms to music production studios. These room acoustics are sampled together with head-related transfer function (HRTF) measurements, which describe how the ear receives sound from a point in space. The BRIRs have been acquired with purpose-built binaural microphones, placed in the ears of real people wearing head-trackers while a test sound is played from speakers placed in the room. Sampled BRIRs are stored together with corresponding head-tracker data, providing information about relative source versus listener angle for each specific sampling.



The measurement of BRIR



Screenshot of the measurement tool for BRIR acquisition

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Synthesis

The BRIR raw data from various optimal listening environments is post-processed and combined to build the speaker-in-a-room listening experience for headphones, so that it is natural, comfortable, and transparent. If done wrong, this easily introduces undesired negative effects, such as comb-filtering coloration and exaggerated reverberation.

A further challenge is to implement the resulting BRIR in a small DSP footprint suitable for battery-powered, wireless headphones.

Dirac has applied several principles to strike a transparent balance between:

- comfortable spatialization
- naturally perceived coloration
- low power consumption

The end result, which runs on a Bluetooth chipset's DSP, is a combination of:

- cascaded, second-order IIR filters to apply both the speaker correction and the target signature sound
- a MIMO FIR filter matrix to restore a transparent crosstalk experience

Conclusion

By applying both spatial correction and spectral correction, Dirac Virtuo™ for Bluetooth Headphones turns any standard stereo content into an immersive sound experience with sound quality custom optimized for the target headphones.

Dirac Virtuo™ offers a practical spatial audio solution for manufacturers while helping to achieve consistent signature sound across product portfolio and ANC modes easier, faster and with lower cost. Meanwhile, consumers enjoy immersive stereo sound from a sea of available standard stereo content with an enhanced headphone sound quality. The sound becomes balanced and transparent for richer detail. When headphones sound like premium stereo speakers, listening is much more comfortable.

About Dirac

Dirac is here to change the world of sound. We're inventing the future of audio with superior experiences for any content, device, and space. For the many, not the few. Based in Sweden, Dirac optimizes digital audio, perfecting sound for better listening in any environment. The patented sound solution technology spans across mobile, gaming, Virtual Reality and Augmented Reality, headphones, streaming, automotive, residential and commercial AV, boosting whatever sound you're listening to, wherever you're listening. For professionals, Dirac produces the industry's most powerful suite of audio tools for signal processing. Some of the world's most respected brands, including Rolls Royce, Volvo, Polestar, BMW, BYD, Harman, Datasat, NAD, ASUS, and OPPO bring the Dirac sound experience to their customers.

Dirac is a global company with headquarters in Uppsala, Sweden and R&D facilities in Copenhagen, Denmark and Bangalore, India, with representation in China, Germany, Japan, Korea, Taiwan and USA.

