Experience Lifelike Spatial Audio

Any App. Any Device. Any Content.

BACCH LABS

BACCH Laboratories

- Exclusive licensing of IP from Princeton University's 3D Audio & Applied Acoustics (3D3A) Research Lab
- Commercial Software for automotive, consumer electronics, and high-end audio companies

List of BACCH Audio Weaver® from DSP Concepts™ Native Modules

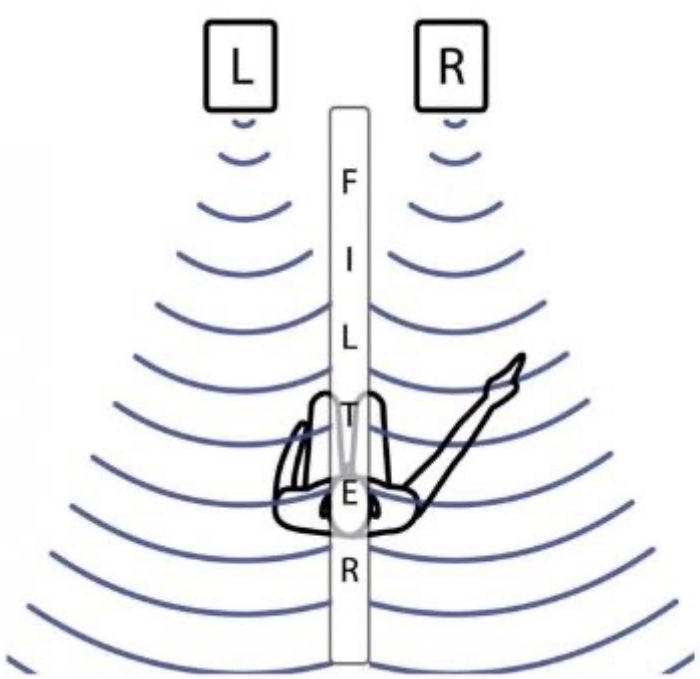
- BACCH-SP-UNI Universal Speakers
  - BACCH for speakers for universal use
- BACCH-SP-MD Measured Speakers
  - BACCH for speakers for measured devices
- BACCH-HP-3D 3D Soundstage
  - BACCH for headphone rendering of a 3D sound stage and virtual speakers
- BACCH-HP-VS Virtual Speakers
  - BACCH for headphone rendering of virtual speakers
- Additional BACCH Audio Weaver Native Modules
  - Can be generated upon request

BACCH Spatial Audio Technologies

BACCH-SP. 3D Sound for Speakers.

Create an unprecedented soundstage from a stereo device.

- Highly acclaimed, spatially accurate 3D Audio process for loudspeakers
- Highest Level of Crosstalk Cancellation (XTC) in the industry
- Works with just 2 speakers. No surround speakers required
- Large Sweet Spot with no tonal coloration and no dynamic range loss
- No penalty outside of sweet spot, with smooth transition and no perceivable change in audio outside of sweet spot
- Steerable sweet spot can be in any location, including tracking the user around the room
- Works with ALL existing and new content without remastering
- Available as an all-software upgrade to Soundbars, TVs, Tablets, Mobile Phones, and Set-Top Boxes



BACCH 3D SOUND invented @ PRINCETON UNIVERSITY

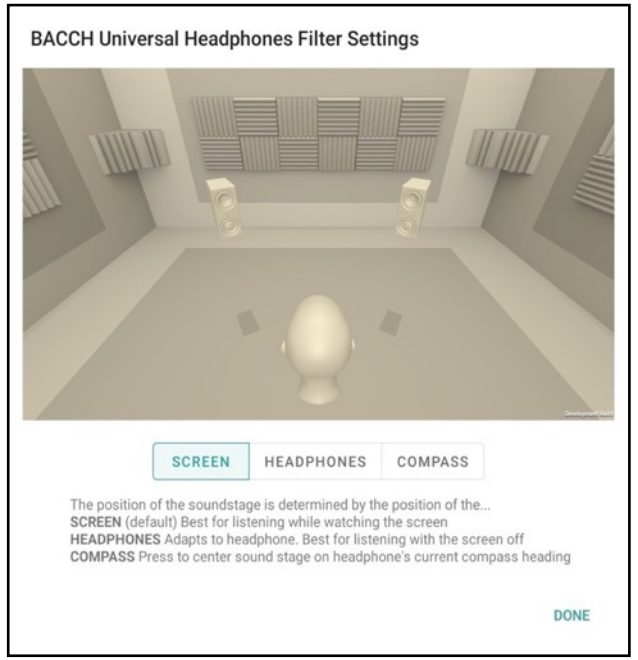
u|BACCH

Add spatial sound to your AVR and set-top-box

- **u**|BACCH stands for Universal BACCH Filter
- **u**|BACCH simply allows the user to adjust the 3D filter half-span angle with a knob until it sounds best to them
- This allows any user on any stereo device to experience BACCH
- Created using a virtual dummy head and virtual speakers in BACCH-dSP, our Mac OS application
- u|BACCH is a series of virtual BACCH filters created at every half-span angle from 0 to 90°

BACCH-HP. 3D Sound for Headphones from BACCH Labs

- Capable of rendering ubiquitous Stereo content onto a 3D Soundstage as if it was Binaural
- Capable of holding a Binaural Soundstage still while the listener turns her head.
  (This is normally impossible with binaural, other technologies reduce the binaural soundstage to a stereo pan.)
- Externalization for nearly 100% of all Listeners
- Highly acclaimed, spatially accurate 3D Audio process invented at Princeton University
- Achieve externalization for near 100% of all listeners without customization
- Supports customization for use with other headphone technologies and measured HRTFs
- BACCH-AHI (Adaptive HRTF Individualization) provides measurement-free customization of rear surround channels **(see next slide).** Gamers will win more games and gets more kills.
- Emulate pristine stereo monitors or create an enveloping 3D soundstage around the listener
- Supports head tracking without the need for a smartphone or other heading reference



BACCH 3D SOUND Invented @ PRINCETON UNIVERSITY

IP No. 1

BACCH™ 3D Sound

(for speakers)

Source: Princeton University

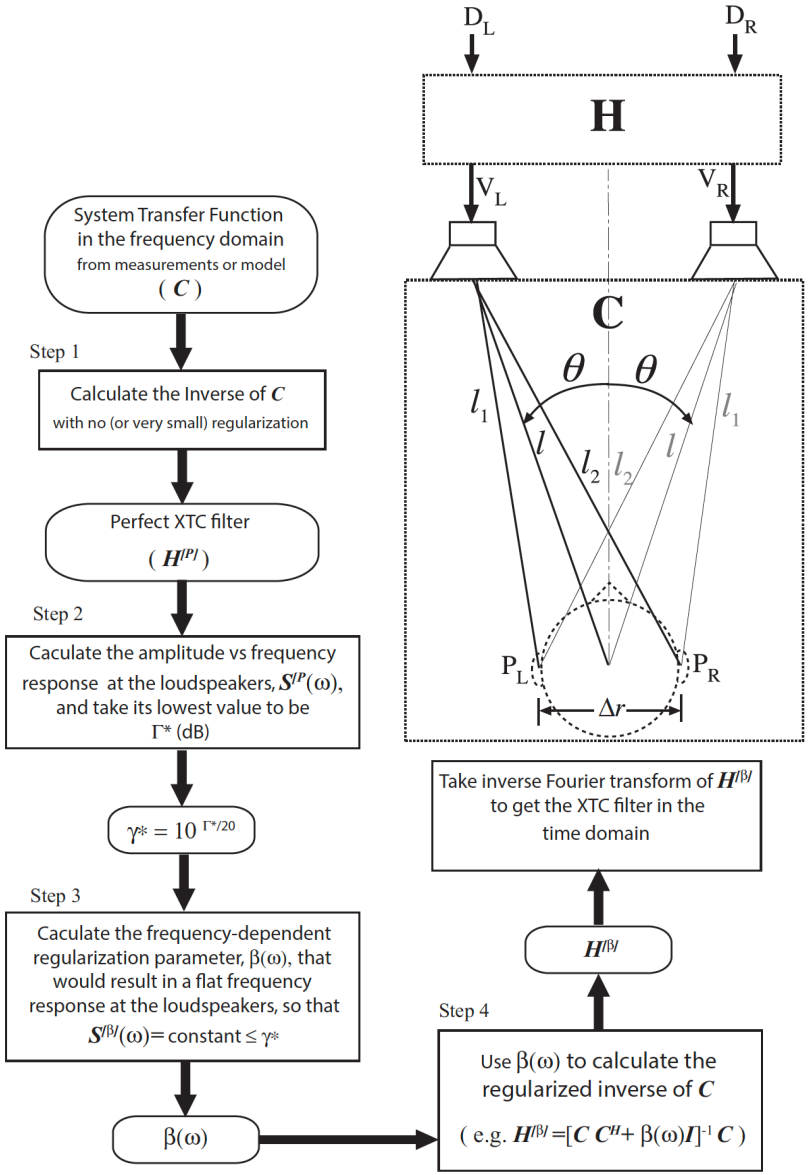
Type: Patent

Spectrally Uncolored Optimal Crosstalk Cancellation for Audio through Loudspeakers

BACCH: **B**and-**A**ssembled **C**rosstalk **C**ancellation **H**ierarchy

BACCH™ 3D Sound gives maximum crosstalk cancellation levels for Binaural Audio through two Loudspeakers (BAL) without introducing any spectral coloration to the input signal or dynamic range loss. Implemented in numerous commercial products. Considered by many leading audio critics (see testimonial slides 8-9) as the best 3D audio rendering technology from two loudspeakers.

Example of use:
1) Driver GPS navigation audio "projected" over road landmarks
2) Audiophile rendering of recordings and live concerts in 3D



IP No.
2

BACCH-HP

(for **h**ead**p**hones)

Source: Princeton University

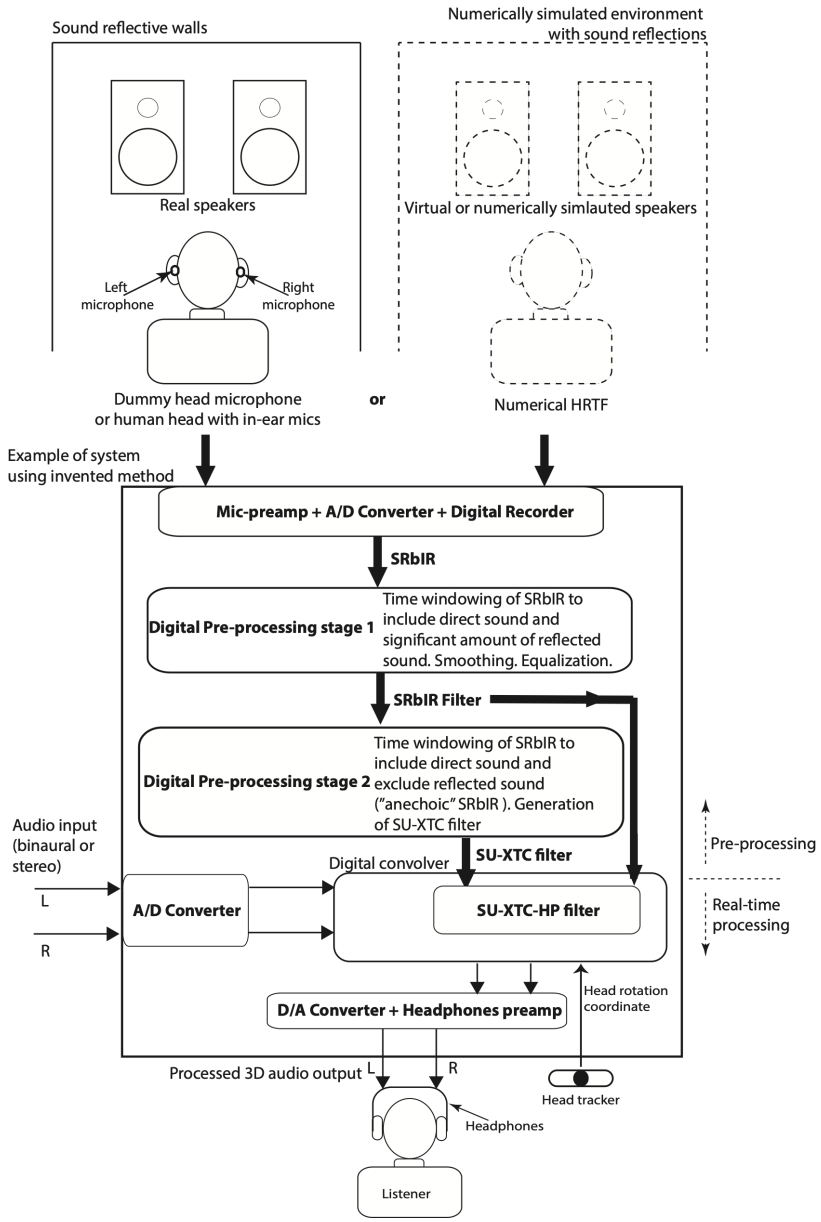
Type: Patent

Head-Externalized 3D Audio through Headphones

The system and method of the present invention rely on combining the **S**peakers+**R**oom **b**inaural **I**mpulse **R**esponse(s) (SRbIR) with a special kind of crosstalk cancellation (XTC) filter — a BACCH filter — that does not degrade or significantly alter the SRbIR's spectral and temporal characteristics that are required for effective head externalization. This unique combination leads to a 3D audio filter for headphones that allows the emulation of the sound of crosstalk-cancelled speakers through headphones, and allows for fixing the perceived soundstage in space using head tracking and thus solves the major problems for externalized and robust 3D audio rendering through headphones. Furthermore, by taking advantage of the well-documented psychoacoustic fact that subjective perception of HRTFs is near-identical for loudspeakers on the horizontal plan with a span of about +/-50° or less, this system and method can produce universal 3D audio filters that work for all listeners i.e. independent of the listener's **h**ead **r**elated **t**ransfer **f**unction (HRTF).

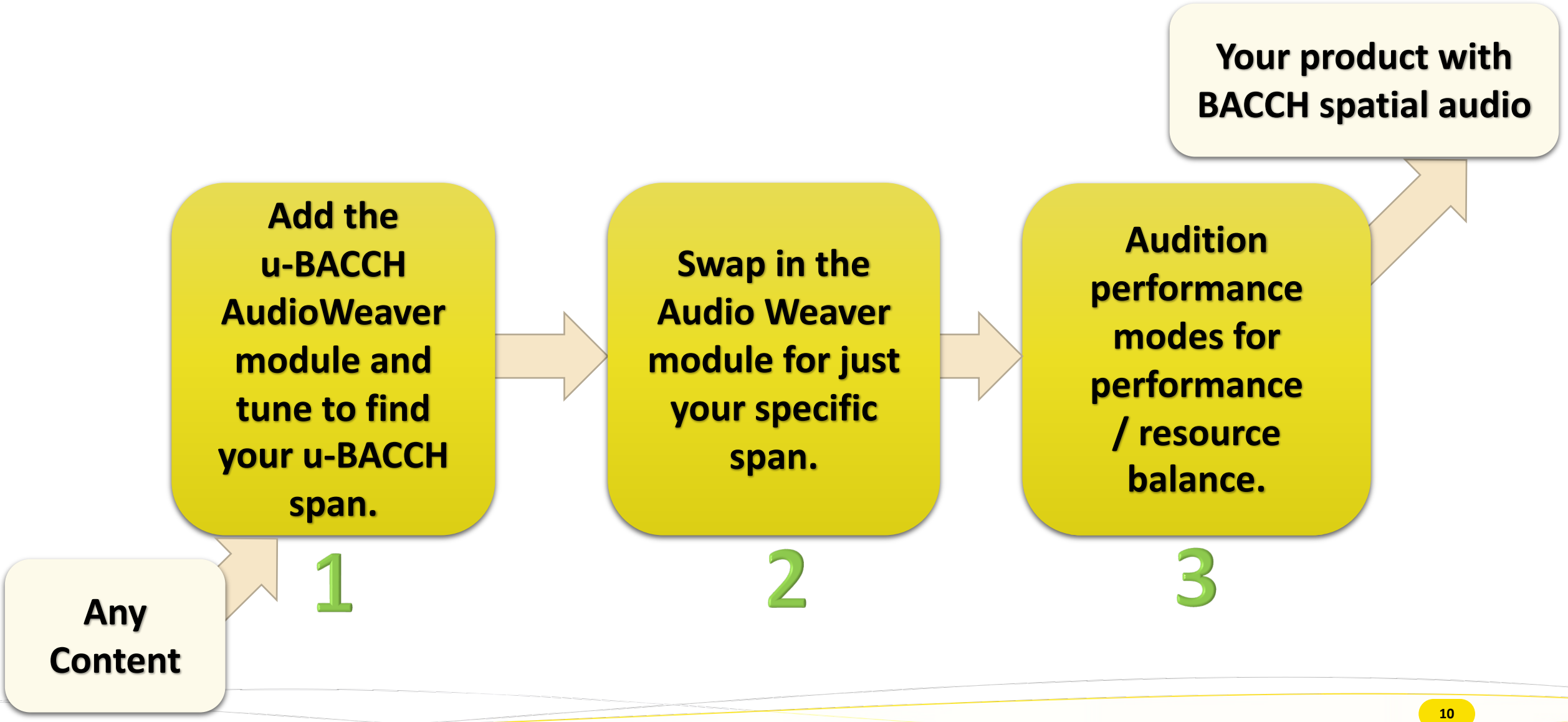
Example of use: Accurate headphones-based rendering of complex 3D acoustical environments without individual calibration

Princeton Docket 14-3047-1. U.S. Patent 9,560,464, issued 1/31/2017; European patent EP3225039, granted 2/17/2021; and Japanese patent application 2017-528571, filed 5/25/2017, each entitled "System And Method For Producing Head-Externalized 3d Audio Through Headphones"

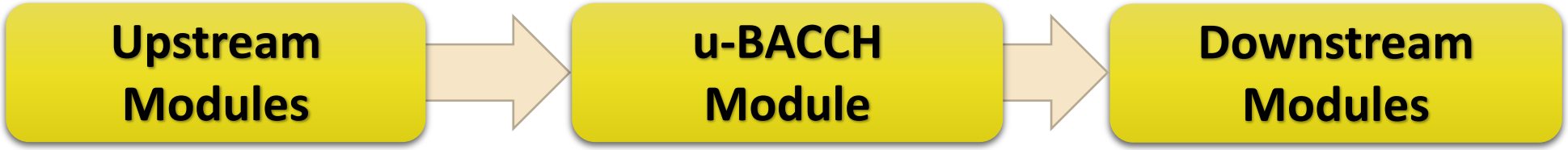


BACCH for Speakers with Audio Weaver® from DSP Concepts™

BACCH Spatial Audio for Speakers, Audio Weaver Workflow



Add the BACCH Module to your audio signal chain



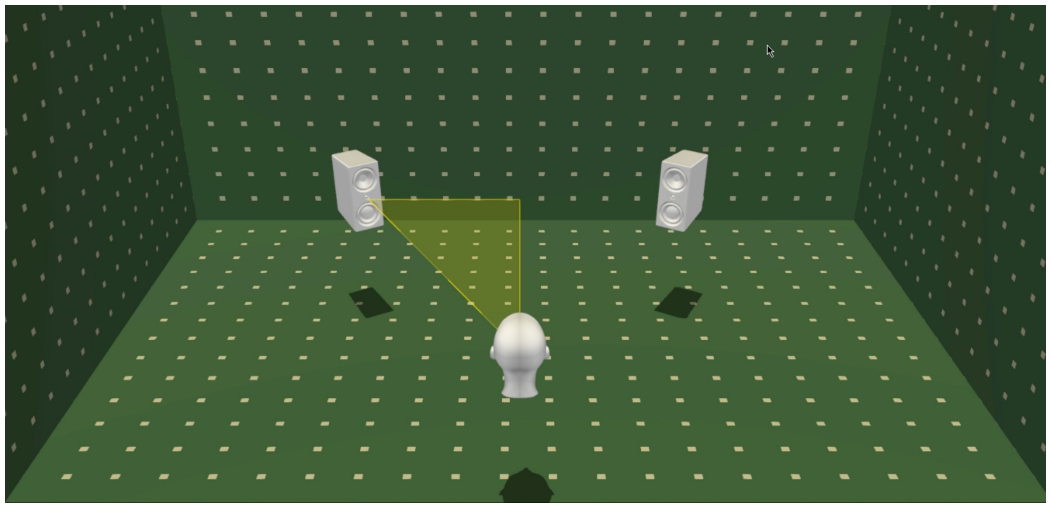
What goes Upstream

- User-selectable EQ
- Conversion to 2-channel including binaural rendering and surround sound virtualization
- Source mixing

What goes Downstream

- No Crossfeed. A signal sent to Left should play as silence on Right and vice versa. Crossfeed will significantly reduce the amount of XTC level possible. If you have crossfeed anywhere in the signal chain you probably want to replace it with BACCH
- Yes, Stereo Link. Every operation should be performed identically on left and right channels. Double check that the “Stereo Linked” checkbox in your compressors actually work
- Always-on (hardware-tuning) EQ

Tune to find your u-BACCH span



u-BACCH, the Universal BACCH filters, is a series of BACCH XTC filters created at every half-span angle from 0 to 90°.

A. An Audio Weaver Design is provided that sends a pink noise signal to just one channel, say Right. **Play the pink noise to Right.** With u-BACCH in Bypass, the sound should come from the Right speaker.

B. Activate BACCH and adjust the span. **The best u-BACCH filter to use is the one where the perceived location of the pink noise is directly to the side of you, close to your ear.** *Note the half-span in degrees.* This may not be the exact angle measured with a protractor; it may be several degrees away.

C. Toggle between BACCH and Bypass to audition the effect with both pink noise and music.

D. Audition the three BACCH Performance Modes: switch between High Resolution, Low Latency, and Lite modes with both pink noise and music (described in next slide).

If you are offering the end-user the ability to change the u-BACCH tuning, for example in an A/V receiver or satellite system, then you are ready to connect the u-BACCH module to your User Interface.

If you are using just a single span, say for a product in a single enclosure, then continue.

Audition performance modes for performance / resource balance.

If your system has the resources to run at high resolution performance all the time, you're done.

If you are limited by processor, memory, and battery constraints, then choose the highest performance mode that meets those constraints. This may be different when on battery power v when on shore power.

Mode	Internal Name	Listening Description	Technical Description
High Resolution (aka Standard)	BACCH10	High Resolution mode is design for uncompromising quality with premium quality sound reproduction equipment wherein refined listeners will be listening for the finest details that are most apparent in jazz and classical pieces. Mono Correction (BACCH-MX) is performed at full performance. The Mono Signal, the part of the source where the left and right signals are 100% correlated, is fully corrected to have identical tambre and level as the side content, all of the content that is not the mono signal. Mono signals are almost nonexistent in acoustic recordings and prevalent in studio mixed content.	Full Mono Correction is computed. Full-length filters are used adding ~25 ms of filter latency at 44.1 kHz.
Low Latency	BACCH5	Low Latency mode demonstrates the low latency demanded by some extreme gamers and demonstrates a reduction in system resource requirements that still deliver a jawdropping user experience with high impact. Low Latency mode provides a fast Mono Correction (BACCH-MX) and provides 100% of the Crosstalk Cancellation of Standard. Refined music listening in Low Latency mode may reveal a less detailed spatial image than Standard Mode. The difference is much more apparent in careful auditions using music and video. The difference is difficult to discern in a First Person Shooter type soundtrack.	Filters are reduced to ¼ the High Resolution length, thus reducing the filter latency to ~6 ms at 44.1 kHz. Mono Correction is performed for the volume of the Mono Signal. Discerning listeners with high resolution equipment may be able to discern a vanishingly small difference in the tambre of the mono signal.
Lite	BACCH1	Lite mode demonstrates the minimum latency and system resource requirements that still deliver a jaw-dropping user experience with high impact. Lite mode forgoes Mono Correction (BACCH-MX) entirely. This is the mode called "Live Audio" that is incorporated into the Jawbone Big Jambox and Jawbone Mini jambox often used as demos and references.	Low Latency mode with Mono Correction completely removed.

BACCH Measured Filters for Speakers

u-BACCH Filters can be upgraded to Measured Filters

Where Universal BACCH Filters shine

- When the impulse response of the hardware is close to a perfect unit impulse response.
- When the speakers are identical and symmetrical (if both transducers are in one enclosure can you ignore the non-symmetric stuff in there?)
- When the speakers are on-plane with the listener's ears.
- When the frequency response of the speakers is relatively flat.
- When the directionality of the loudspeakers is similar at all frequencies
- Where you have satellite speakers where the span will be determined by the user
- Where you want the end-user to tune u-BACCH for an arbitrary device
- When you want to make a quick filter that you may or may not want to measure later

Where Universal BACCH Filters can be improved with a bespoke measured filter

- The measured filter is almost always better, it's just that the conditions of the left make the difference almost imperceivable
- Heavily asymmetric devices (phones) usually require a measured filter
- The Mono Signal performance in Lite Mode can sometimes be significantly improved with a measured filter

You can decide. Build or download the Audio Weaver Design that allows you to switch between these modes for the Jawbone Mini Jambox:

- The Measured Lite Mode filter Embedded in the Mini Jambox, Live Audio
- The Measured filter for the Jambox provided as an AWE Module
- A U-BACCH filter for the Jambox

Measured Filter Sources

Filter measurement is a service provided by BACCH Labs

- The BACCH team will apply an extensive toolbox of features to bespoke a measured filter to our exacting standards.
- First-pass test filters can often be made available the same day your product is received.
- Contact BACCH directly or through your DSP Concepts representative: https://audioinnovation.dspconcepts.com/speak-with-specialist

The filter measurement system is available for purchase

- Generate an unlimited number of BACCH filters using BACCH-dSP, the BACCH desktop Signal Processor
- Quickly switch test Bypass, Measured, and universal BACCH filters.
- Extensive toolbox is ideal for those interested in controlling every nuance of filter generation themselves. Technical training is provided.

Ready to Experience BACCH 3D Sound? Available in Audio Weaver!

Or contact BACCH Labs today.

Cole@BACCH.com