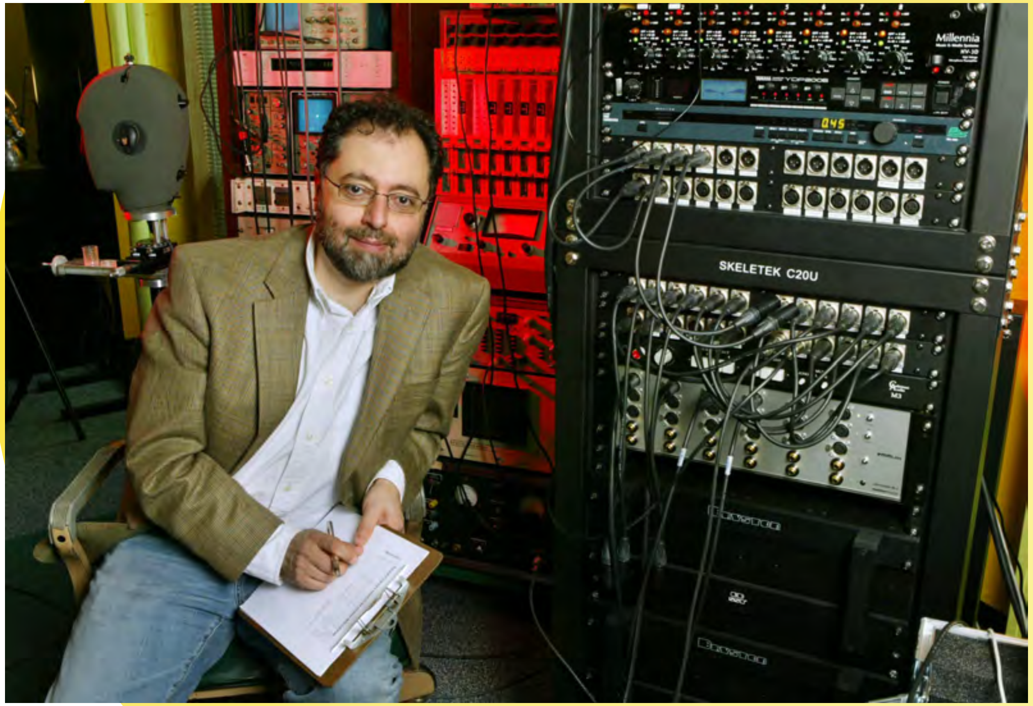

3D3A @ PRINCETON UNIVERSITY
Research Lab
BACCH LABS
BACCH Labs IP
BACCH 3D Sound
BACCH-HP
BACCH-AHI
BACCH-X
MAHHLER
...
High-End Audio Products
BACCH LABS
The Front End of Princeton's 3D3A Lab



BACCH Lab’s
62 Intellectual Property Items

- 8 Patents
- 25 Proprietary Algorithms and Methods
- 26 Software Packages / Apps
- 2 Hardware Packages
- 1 Registered Trademark

BACCH Labs IP List 8 Patents

(See individual slides for more details on each patent)

No.	Source	Type	Short Name	Description
1	Princeton	Patent	BACCH™ 3D Sound (for speakers)	Princeton Docket 11-2648-1. U.S. patent 9,167,344, issued 10/20/2015; Chinese patent ZL 201180042554.2, issued 6/15/2016; Japanese patent JP5993373, issued 9/14/2016; European patent EP2612437, issued 11/18/2015; Korean patent KR1768260, issued 8/8/2017; and Hong Kong patent HK1187454, issued 9/15/2017, each entitled "Spectrally Uncolored Optimal Crosstalk Cancellation for Audio Through Loudspeakers"
2	Princeton	Patent	BACCH-HP (for **h**eadp**h**ones)	Princeton Docket 14-3047-1. U.S. patent 9,560,464, issued 1/31/2017; European patent EP3225039, issued 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"
3	Princeton	Patent	BACCH-IRNR (**I**mpulse **R**esponse Measurement with **N**oise **R**ejection)	Princeton Docket 14-3048-1. U.S. patent 9,959,883, issued 5/1/2018, entitled "A Method and System for Producing Low Noise Acoustical Impulse Responses at High Sampling Rate"
4	Princeton	Patent	BACCH-SFN (**S**ound **F**ield **N**avigation)	Princeton Docket 17-3288-1. U.S. patent 11,032,663, issued 6/8/2021, entitled "System and Method for Virtual Navigation of Sound Fields Through Interpolation from an Array of Microphone Assemblies"
5	Princeton	Patent (Pending)	MAHHLER (**M**ulti-Listener **A**udio wit**h H**igh-Isolation De**l**iv**er**y)	Princeton Docket #19-3528-1. U.S. disclosure 7/18/2018, entitled "Mixed Radiation Loudspeaker Array for Producing Acoustically Isolated Audio Zones." Filing number F149-B-61912 filed in France on October 6, 2021.
6	BACCH Labs	Patent (Pending)	BACCH-AHI (**A**daptive **H**RTF **I**ndividualization)	BACCH Labs Docket BCC.110P. U.S. patent application, entitled "Adaptive HRTF Individualization for Surround Sound Virtualization." US Provisional Patent Application 63/340,141; filed May 10, 2022
7	BACCH Labs	Patent	BACCH-RVR (**R**oom-scale **V**irtual **R**eality)	BACCH Labs Docket BCC.103P/104P. U.S. patent 9,363,602, issued 6/7/2016, entitled "Method and Apparatus for Providing Virtualized Audio Files via Headphones"; and continuation in part U.S. Patent 10,129,682, issued 11/13/2018, entitled "Method and Apparatus to Provide a Virtualized Audio File"
8	BACCH Labs	Patent	BACCH-ESS (**E**nhanced **S**urround **S**ound)	BACCH Labs Docket BCC.109XC1. U.S. patent 10,123,120, issued 11/6/2018, entitled "Method and Apparatus for Providing 3D Sound for Surround Sound Configurations"

BACCH Labs IP List – 25 Algorithms

(See individual slides for more details on each algorithm)

No.	Source	Type	Short Name	Description
9	Princeton	Algorithm	BACCH-HEADS	HRTF Extractor using a Database of Spherical-Harmonic-Correlated Measurements and Head Scans
10	Princeton	Algorithm	BACCH-CTD	Characterization of Transducer Directivity
11	Theoretica	Algorithm	BACCH-BFD	BACCH Filter Designer
12	Theoretica	Algorithm	BACCH-ABFD	Automatic BACCH™ Filter Designer
13	Theoretica	Algorithm	BACCH-X	Multiple Sweet Spot Audio Delivery Using Phase Array
14	Theoretica	Algorithm	BACCH-RHD	Robust Head-related Impulse Response Densification
15	Theoretica	Algorithm	BACCH-ZfSC	Zipper-noise-free Sliding Convolution
16	Theoretica	Algorithm	.bac File Format	Encrypted File Format for Proprietary FIR Filters
17	Theoretica	Algorithm	BACCH-HEQ	Headphones Equalization
18	Theoretica	Algorithm	BACCH-HNfE	HRTF Near-field Extension
19	Theoretica	Algorithm	BACCH-LyRE	Listening Room Emulation
20	Theoretica	Algorithm	BACCH-MCC	Mono Component Correction
21	Theoretica	Algorithm	BACCH-DiFEQ	Diffuse Field Equalization
22	Theoretica	Algorithm	BACCH-BMC	Binaural Microphone Calibration
23	Theoretica	Algorithm	u-BACCH	Universal BACCH™ Filter
24	Theoretica	Algorithm	BACCH-Htap	Head-Tracked Audio Processor
25	Theoretica	Algorithm	BACCH-HTRC	Head-Tracked Room Correction
26	Theoretica	Algorithm	BACCH-VLS	Virtual Loudspeakers
27	Theoretica	Algorithm	BACCH-3dm	3D Mixer
28	Theoretica	Algorithm	BACCH-TRJ	3D Trajectory designer
29	Theoretica	Algorithm	BACCH-HT-Nav	Head-tracked Navigation
30	Theoretica	Algorithm	BACCH-HOA	Higher Order Ambisonics
31	Theoretica	Algorithm	BACCH-hs^3	Head-Steered Sound Spotlight
32	Theoretica	Algorithm	BACCH-sme	Stereo Mic Emulation
33	Theoretica	Algorithm	BACCH-BM Pro	In-ear Binaural Microphone

BACCH Labs IP List – 26 Software Packages

(See individual slides for more details on each software package)

No.	Source	Type	Short Name	Description
34	Theoretica	Software	BACCH-dSP	**d**esktop **S**ignal **P**rocessor
35	Theoretica	Software	BACCHp Plugin	Sliding Convolver **P**lugin
36	BACCH Labs	Software	BACCH AHI	**A**daptive **H**RTF **I**ndividualizer application
37	BACCH Labs	Software	BACCH Ba1 format	A container with all of the information to perform BACCH 3D rendering in a particular device
38	BACCH Labs	Software	BACCH Device Library	Library of measured filters
39	BACCH Labs	Software	BACCH Core Library	A monolithic-to-the-customer library that supports processing all signal flows requested by Ba1 file
40	BACCH Labs	Software	BACCH API	The **A**pplication **P**rogramming **I**nterface to the BACCH Core Library
41	BACCH Labs	Software	Compressor	Single-band and multi-band compressors
42	BACCH Labs	Software	S-BACCH	**S**oftware-as-a-Service BACCH
43	BACCH Labs	Software	BACCH4Kalimba	BACCH4Kalimba
44	BACCH Labs	Software	BACCH4ADAU	BACCH4ADAU
45	BACCH Labs	Software	BACCH4ALSA	BACCH4Alsa
46	BACCH Labs	Software	BACCH4Hexagon	BACCH4Hexagon
47	BACCH Labs	Software	Raspberry Pi Demo with HiFiBerry	Raspberry Pi Demo with HiFiBerry SPDIF Board
48	BACCH Labs	Software	Beagleboard Demo and HDK	Beagleboard Demo and HDK
49	BACCH Labs	Software	BACCH SDK for Android	BACCH SDK for Android
50	BACCH Labs	Software	BACCH SDK for Apple	BACCH SDK for Apple
51	BACCH Labs	Software	BACCH SDK for Windows	BACCH SDK for Windows
52	BACCH Labs	Software	BACCH Android Demo App	BACCH Android Demo App
53	BACCH Labs	Software	BACCH Apple Demo App	BACCH Apple Demo App
54	BACCH Labs	Software	BACCH IMU Demo	Head tracking with MetaMotionR IMU (**I**nertial **M**easurement **U**nit) App Module
55	BACCH Labs	Software	AOSP Build	AOSP Build for Nexus 6P
56	BACCH Labs	Software	Surround Sound Virtualization	Surround Sound Virtualization
57	BACCH Labs	Software	BACCH Unity Plug-Ins	BACCH Unity Plug-Ins, covers Spatializer, Effects, and Surround Sound Support
58	BACCH Labs	Software	Multi-Channel Extraction	**M**ulti-**C**hannel **Ex**traction
59	BACCH Labs /Joint	Software	Secure Network Database Access	Code for secure Network Database Access and Server Synchronization

BACCH Labs IP List – 2 Hardware Packages and 1 Trademark

No.	Source	Type	Short Name	Description
60	Theoretica	Hardware	BACCH-BM Pro	in-ear **B**inaural **M**icrophone
61	BACCH Labs	Hardware	Sweet Spot Automated Test System	Sweet Spot Servo Automation
62	Princeton	Trademark	BACCH Trademark	BACCH Trademark

A slide on each IP item follows.

BACCH™ 3D Sound
(for speakers)

IP No. 1

Source: Princeton University
Type: Patent

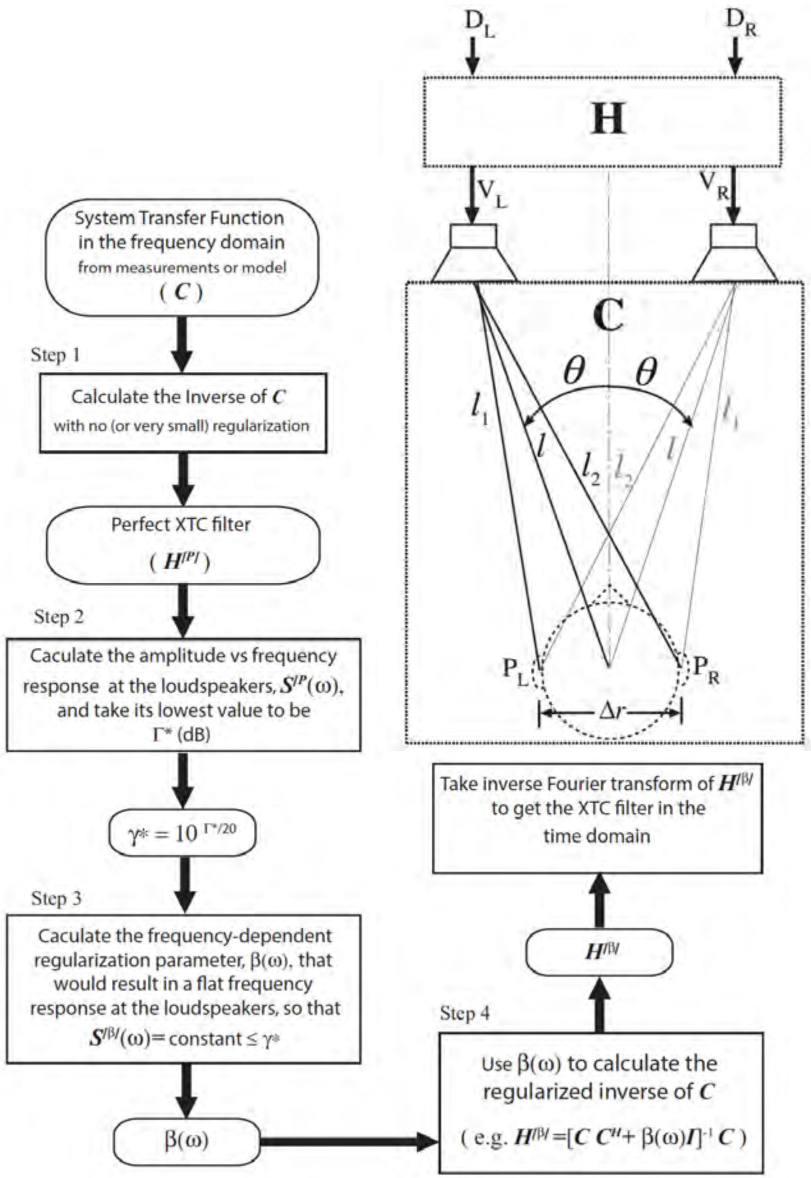
Spectrally Uncolored Optimal Crosstalk Cancellation for Audio through Loudspeakers

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

Princeton Docket 11-2648-1.U.S. Patent 9,167,344, issued 10/20/2015; Chinese patent ZL 201180042554.2, issued 6/15/2016; Japanese patent JP5993373, issued 9/14/2016; European patent EP2612437, issued 11/18/2015; Korean patent KR1768260, issued 8/8/2017; and Hong Kong patent HK1187454, issued 9/15/2017 each entitled "Spectrally Uncolored Optimal Crosstalk Cancellation For Audio Through Loudspeakers"



IP No. 2

BACCH-HP
(for headphones)

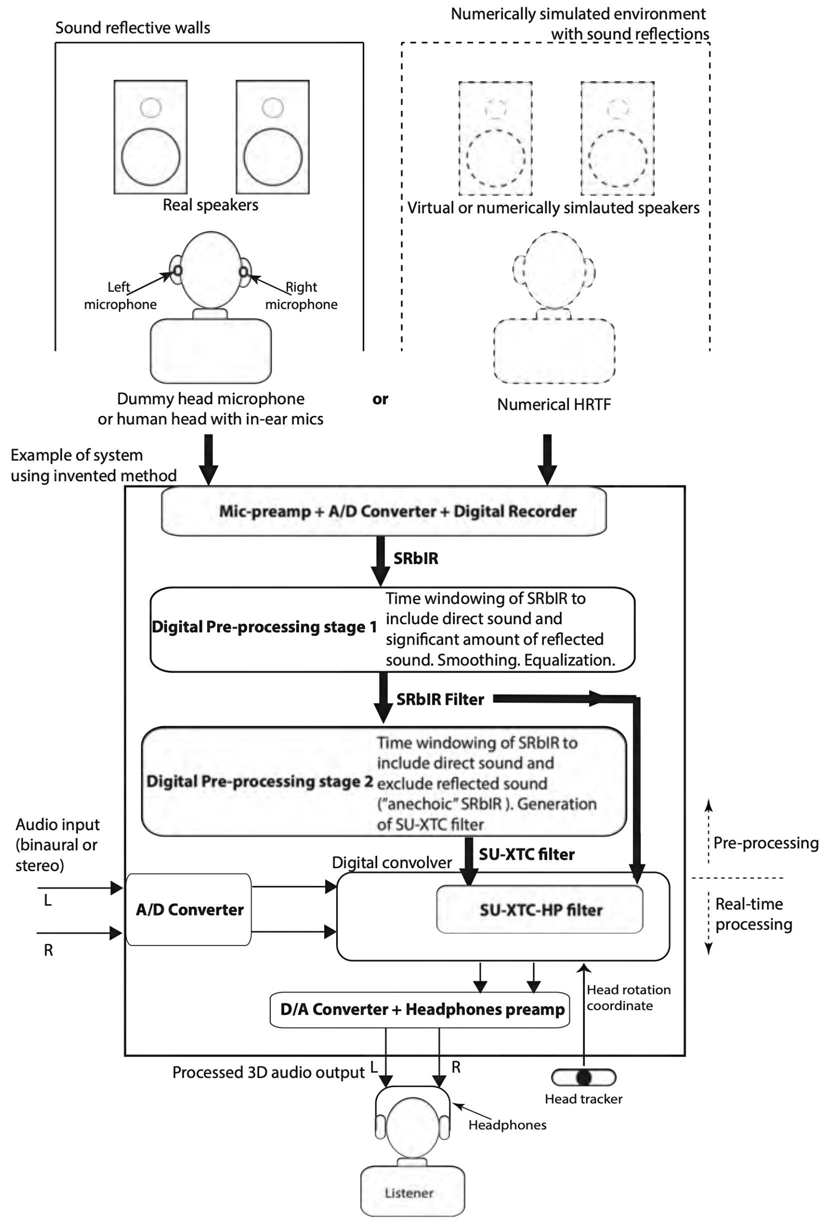
Source: Princeton University
Type: Patent

Head-Externalized 3D Audio through Headphones

The system and method of the present invention rely on combining the Speakers+Room binaural Impulse Response(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 head related transfer function (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"



IP No. 3

BACCH-IRNR

(Impulse Response Measurement with Noise Rejection)

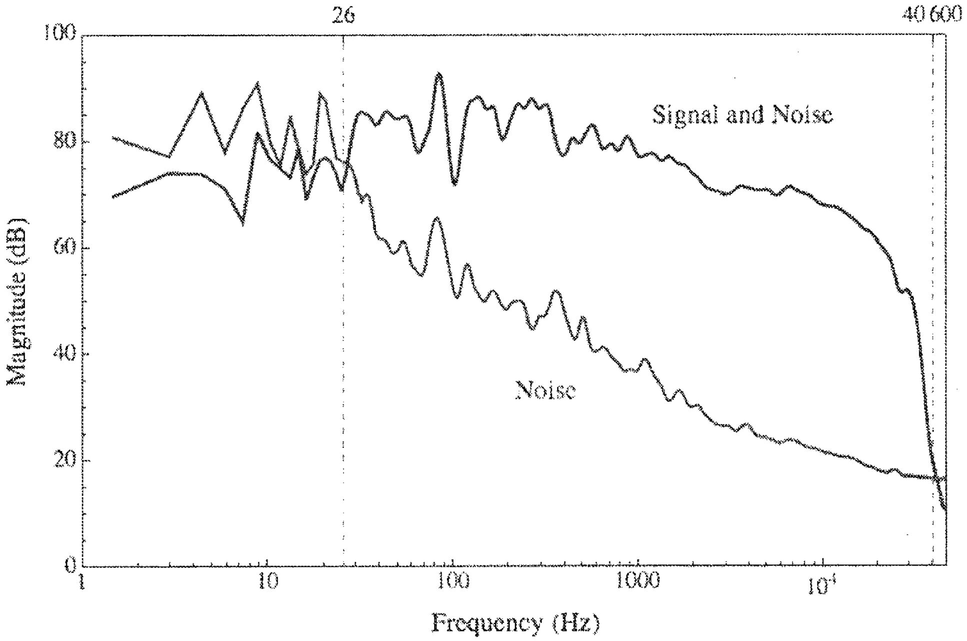
Source: Princeton University
Type: Patent

A Method and System for Noise Rejection in Acoustical Measurements

The method and system utilize two exponential sine sweeps to measure impulse responses. A first, quick sweep up to the Nyquist frequency provides an estimate of the system response and ambient noise. This measurement is used to algorithmically determine an appropriate pass-band of the system. A second, slower sweep through the pass-band alone is then executed and a corresponding band-pass filter is applied to the resulting output signal to suppress noise. The result is a measured impulse response with an improved signal-to-noise ratio and a much-reduced pre-response.

Example of use: Accurate measurement of the transfer function of a complex audio system in the noisy environment of a moving car cabin

Princeton Docket 14-3048-1. U.S. Patent 9,959,883, issued 5/1/2018, entitled "A Method and System for Producing Low Noise Acoustical Impulse Responses at High Sampling Rate"



Sampled noise floor, the initial measurement's frequency spectrum, and the optimal-SNR (signal-to-noise ratio) pass-band. The initial sweep has an SNR of 21 dB. The Optimal SNR is 38 bB with a **p**eak **d**eviation **a**mplitude (PDA) of <0.2%. The algorithm has selected the widest possible frequency range with an SNR of 24 dB and a Constrained-PDA of <0.4%.

IP No. 4

BACCH-SFN
(Sound Field Navigation)

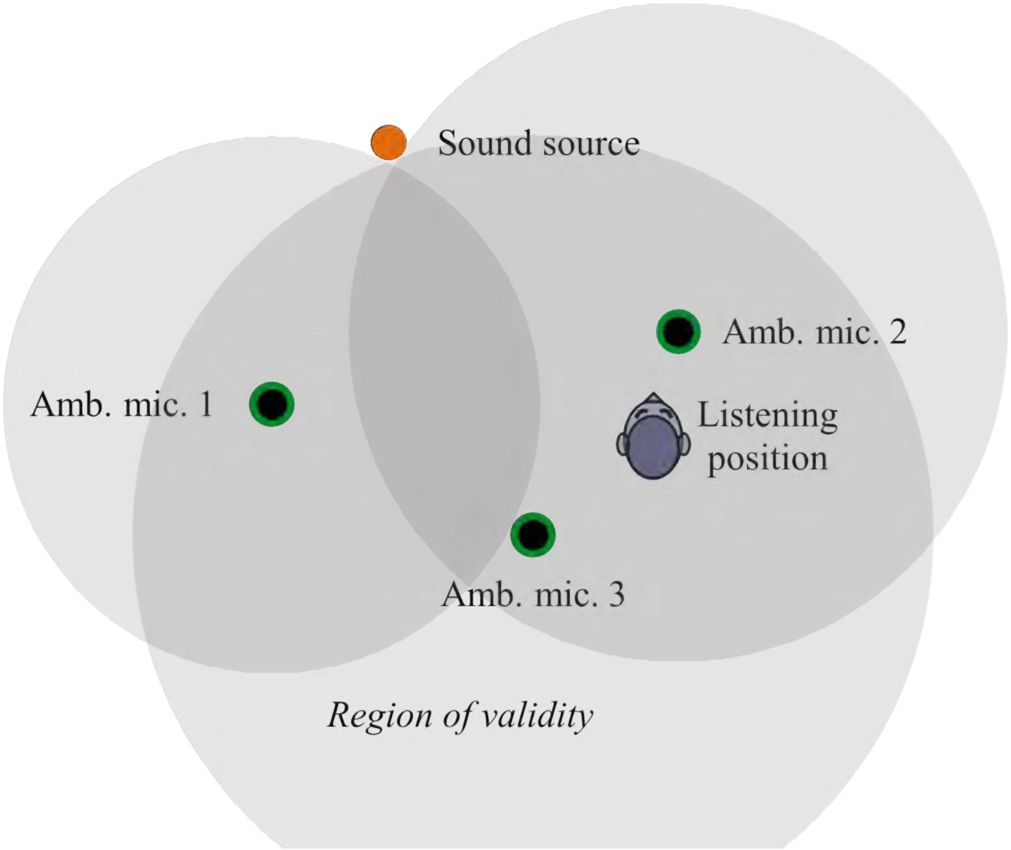
Source: Princeton University
Type: Patent

Navigable 3D Sound Fields from Arrays of HOA Microphones

The system and method for virtual navigation of a sound field through interpolation of the signals from an array of microphone assemblies utilizes an array of two or more higher-order Ambisonics (HOA) microphone assemblies, which measure spherical harmonic coefficients (SHCs) of the sound field from spatially-distinct vantage points, to estimate the SHCs at an intermediate listening position. First, sound sources near to the microphone assemblies are detected and located. Simultaneously, the desired listening position is received. Only the microphone assemblies that are nearer to said desired listening position than to any near sources are considered valid for interpolation. The SHCs from these valid microphone assemblies are then interpolated using a combination of weighted averaging and linear translation filters. The result is an estimate of the SHCs that would have been captured by a HOA microphone assembly placed in the original sound field at the desired listening position.

<u>Example of use:</u> Remote rendering of a 3D sound field from the vantage of various locations, without moving the microphones

Princeton Docket 17-3288-1. U.S. patent application 16/338,078 filed 3/29/2019, Notice of Allowance on 2/22/21, entitled "System and Method for Virtual Navigation of Sound Fields Through Interpolation From an Array of Microphone Assemblies"



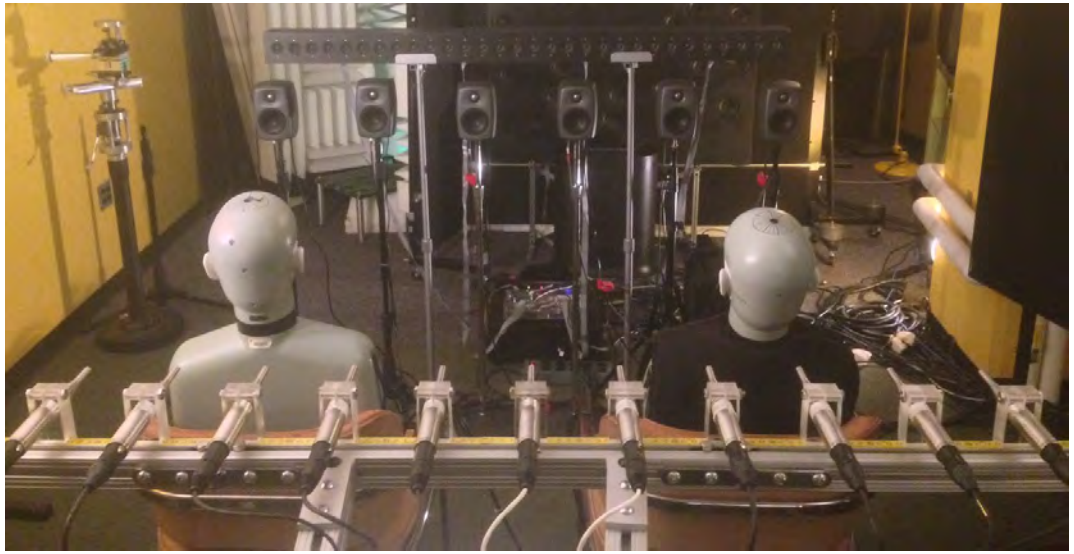
IP No.
5

MAHHLER

(Multi Listener Audio with High-Isolation Delivery)

Source: Princeton University
Type: Patent

Personal Sound Zones Creation Using Mixed Loudspeaker Arrays



The MAHHLER technology, the result of three years of research at the 3D3A Lab, uses an array of loudspeakers, advanced beam formation and digital processing, to create personal sound zones (PSZ) with unprecedented levels of inter-zone isolation for delivering a program to a given zones while the other zones remain isolated, or different programs to different zones. MAHHLER's personal sound zones have enhanced robustness to head movements and acoustic reflections.

Example of use: Acoustically-isloated personal sound zones in a car cabin or commercial airliner

Princeton Docket #19-3528-1, Disclosured 7/18/2018. "Mixed Radiation Loudspeaker Array for Producing Acoustically Isolated Audio Zones."

IP No. 6

BACCH-AHI

(Adaptive HRTF Individualization)

Source: BACCH Labs

Type: Patent

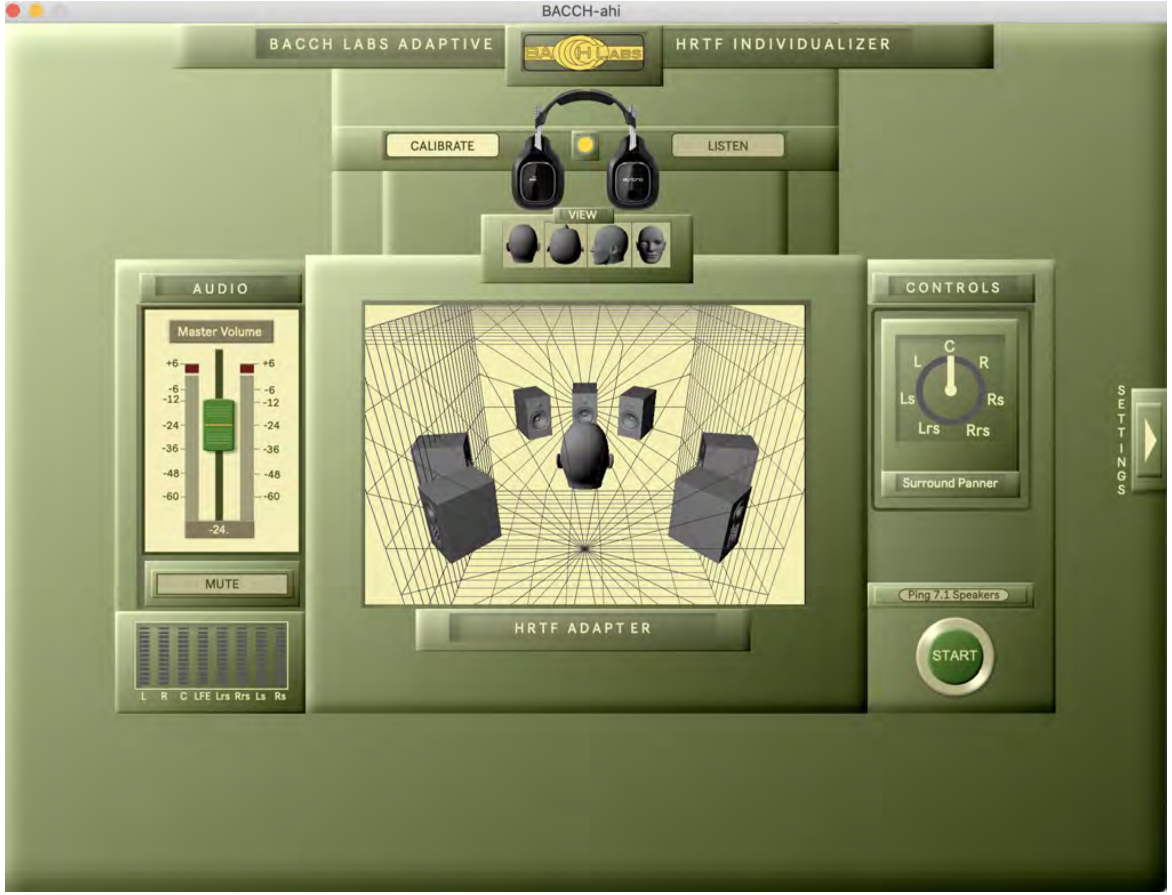
Adaptive HRTF Individualization

A robust technique for obtaining filters that individualize 3D audio rendering over headphones to insure head externalization of sound by relying on a simple calibration procedure by the listener. The calibration relies on the listener's feedback on the perceived locations of specific sound sources as the system composes a composite individualized HRTF from a large database of especially selected and serialized HRTFs.

<u>Example of use:</u> Individualized HRTF-based rendering of a loudspeaker system over headphones without the effort, cost, and complexity of measuring the individual's HRTF

BACCH-AHI was implemented as a standalone application (IP#36) for the Mac and Windows OS.

BACCH-Labs Docket BCC.110P. U.S. patent application "Adaptive HRTF Individualization for surround sound virtualization"



IP No. 7

BACCH-RVR

(Room-Scale Virtual Reality)

Source: BACCH Labs

Type: Patent

Providing Room Scale VR Using Headphones with a Position Tracker

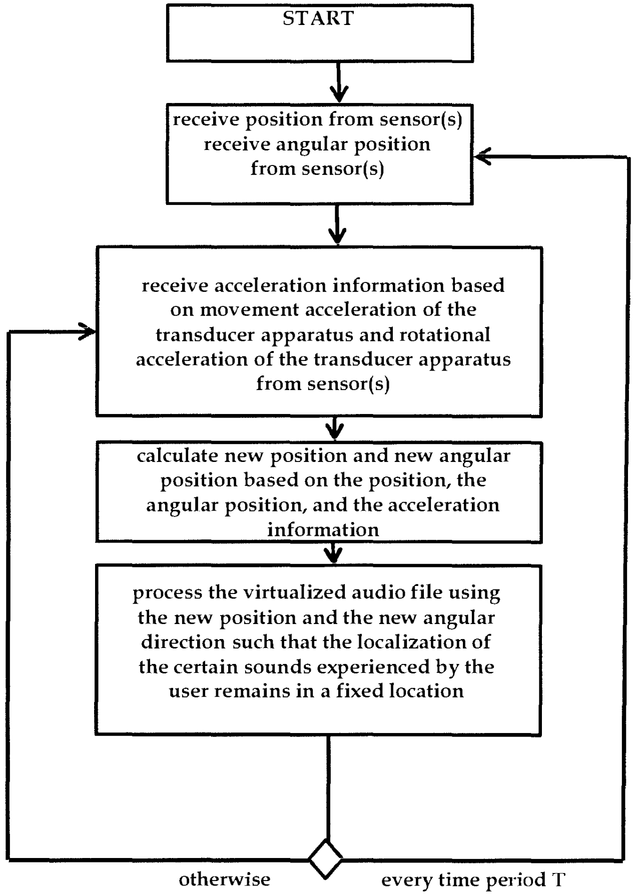
A method of gathering Room Scale VR data from position sensors on objects and headphones, slide through which HRTF is applied to an audio stream associated with each sensor, and render all of the sound as binaural.

Examples of use: The patent snapshots an early demonstration of the company's head tracking where all of the processing was done a central device and the head trackers are on objects and eyewear, such as the original Epson AR glasses where the headwear and controller were separate units.

Today, a similar configuration is used as part of the company's Android head tracking demo app. This app takes inputs from a Bluetooth head tracker that is clipped onto a paid of headphones. This configuration is primarily used for demo as products should incorporate the head tracker into smart headphones to remove the lag of the head tracker sending data to the app and the lag of the app's buffering.

The claims may cover some of the future applications requested by our Creative Advisors in which position trackers are attached to objects on a movie set and then sounds are attached to the tracking points on the objects.

US Patent 9,363,602 Issued 6/7/2016, entitled "Method and apparatus for providing virtualized audio files via headphones" and US Patent 10,129,682 Issued 11/13/2018, entitled "Method and apparatus to provide a virtualized audio file"



IP No. 8

BACCH-ESS
(Enhanced Surround Sound)

Source: BACCH Labs
Type: Patent

BACCH-Enhanced Surround Sound

A method of using BACCH XTC technology with surround sound systems. BACCH-ESS treats surround sound systems as a series of speaker pairs and provides and XTC filter for each pair. Though an audio object can be rendered through any one of the crosstalk cancelled speaker pairs, each audio object is mixed into the speaker pair with the closes angular position to the object.

If all of the speaker pairs were perfectly filtered, the room was perfectly treated, and the HRTF used to render the audio object was matched to the listener, the listener would be unable to distinguish which speaker pair was rendering the audio object. In practical setups the surround sound speakers are often positioned to avoid furniture, the room treatments are not idea, and the HRTF in not matched to the listener. In these real-world conditions an audio object can start retreating from the target rendering location to the speaker pair, and in these cases rendering the object to the nearest speaker pair provides the most benefit.

Examples of use: The BACCH-ESS system has been demonstrated with PC Desktop Gaming with the Unity Game engine. In this case, there is considerable Front/Back confusion when listening for other players in First-Person-Shooter games. BACCH-ESS correctly resolves the Front/Back confusion in favor of the direction of the correct pair of physical speakers. In addition, the overall SPL levels can be higher because of the larger total number of loudspeakers in use.

US Patent 10,123,120 issued 11/6/2018, entitled "Method and Apparatus for Providing 3D Sound for Surround Sound Configurations"

Other than the Center and LFE channels, Surround Sound configurations are made up on pairs of speakers that are ideally left/right symmetrical. BACCH for Surround Sound Systems combines the benefits that BACCH provides on as few as two speakers with the advantages of multiple pairs of speakers offered by surround sound systems.

IP No. 9

BACCH-HEADS

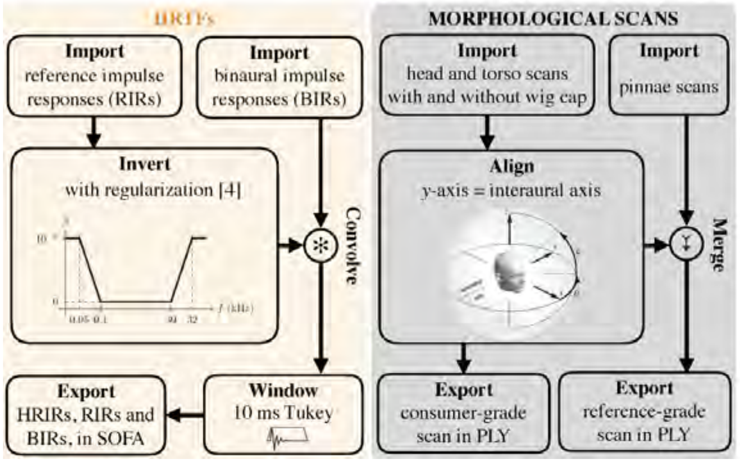
(HRTF Extractor using a Database of Spherical-Harmonic-Correlated Measurements and Head Scans)

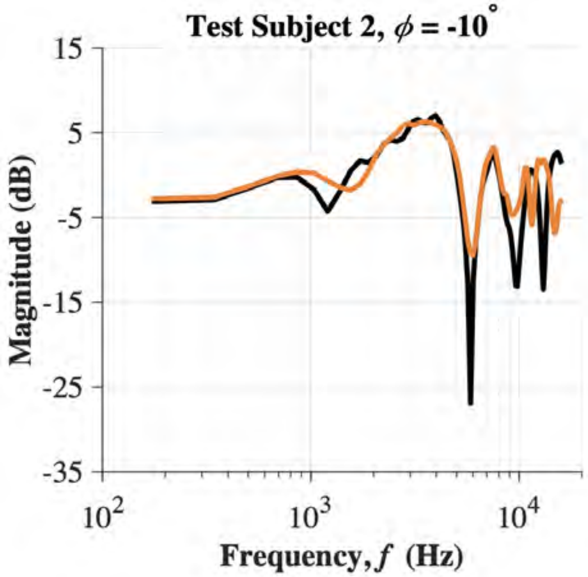
Source: Princeton University
Type: Algorithm

A Method for Efficiently Calculating Head-Related Transfer Functions (HRTFs) Directly from Head Scan Point Clouds of a Subject Using a Large Database of Spherical-Harmonic-Correlated Head Scans and Measured HRTFs

Many applications in spatial audio rely critically on individualized HRTFs that can be estimated accurately and efficiently, but existing methods do not simultaneously meet these requirements.

BACCH-HEADS developed recently at Princeton's 3D3A Lab uses efficient matrix multiplications to compute HRTFs from spherical harmonic representations of head scan point clouds that may be obtained from consumer-grade cameras.





Black curve is the measured HRTF and the orange curve is the predicted one derived from head scans using the BACCH-HEADS method.

IP No.
10

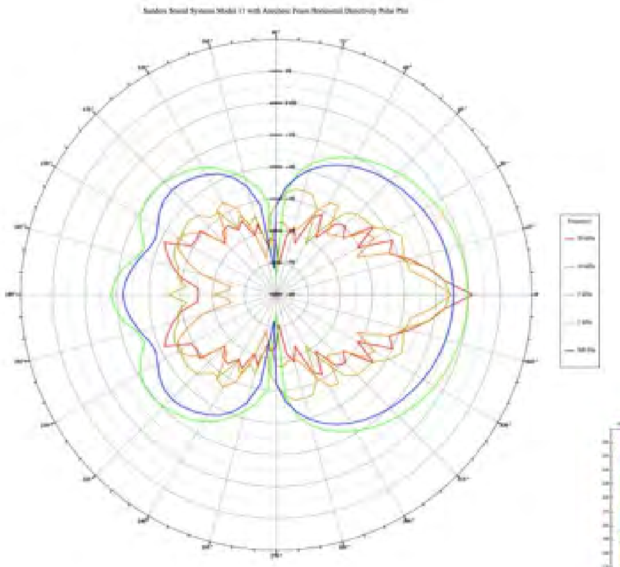
BACCH-CTD
(Characterization of Transducer Directivity)

Source: Princeton University
Type: Algorithm

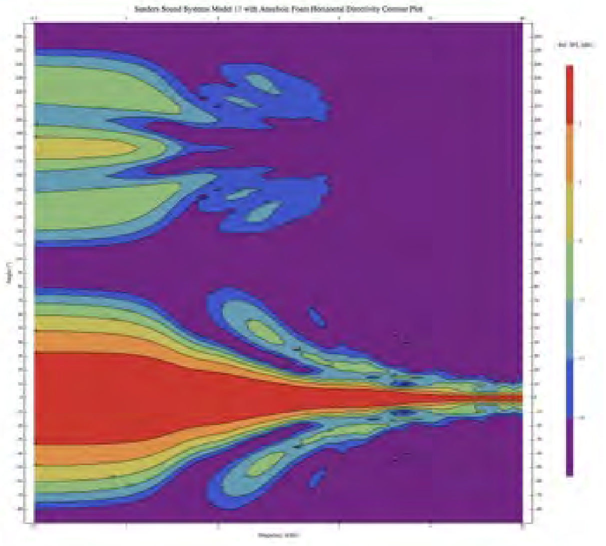
A Suite of Algorithms for the Automatic Measurement of Transducer Directivity in 3D

BACCH-CTD allows for automatic full characterization of the 3D directivity of both speakers and microphones in an anechoic chamber using a programmable high-torque turntable and reference microphone. BACCH-CTD outputs various directivity plots and evaluates directivity indices.

These algorithms and the software based on them were used to generate the large database of speakers directivity measured as part of Princeton's directivity survey.



Full Polar Plot



Full Contour Plot

IP No.
11

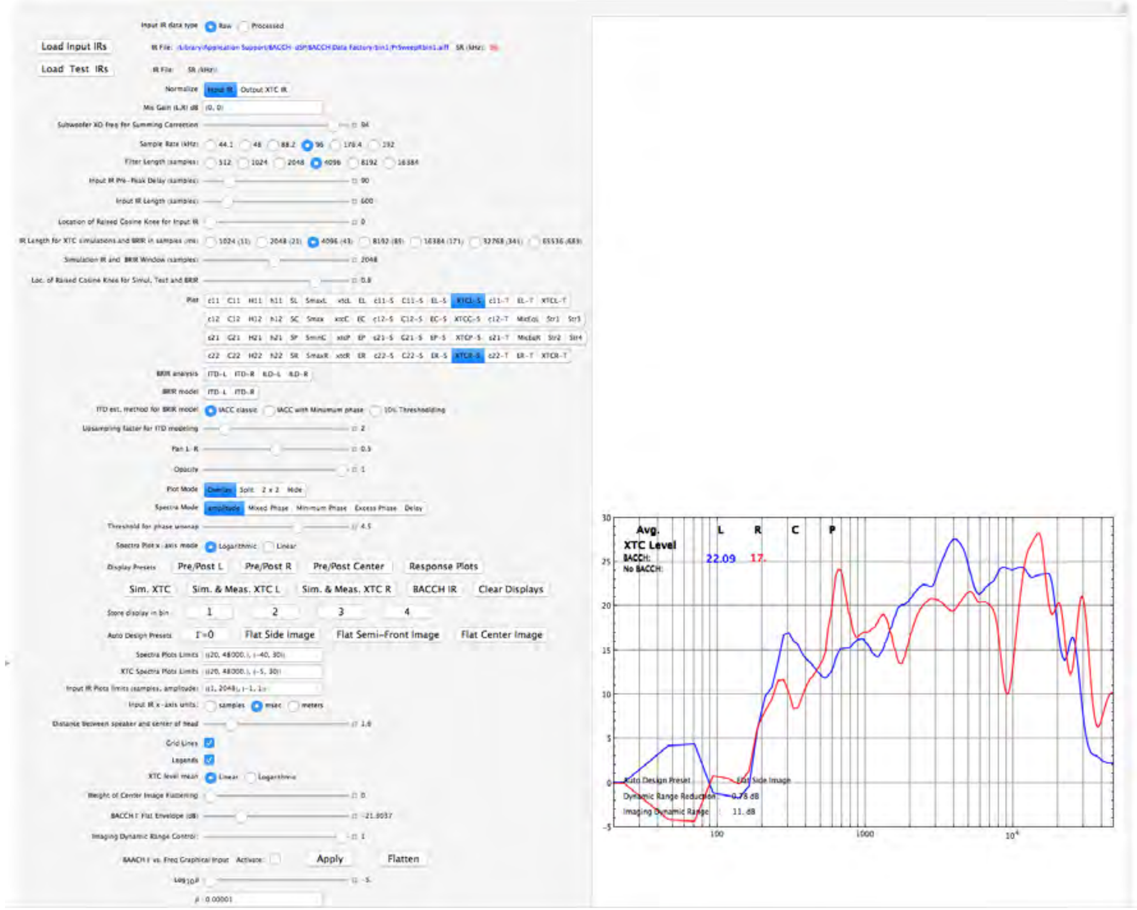
BFD
(BACCH™ Filter Designer)

Source: Theoretica
Type: Algorithm

Algorithm and Code for Designing BACCH™ Filters

The BACCH™ Filter Designer (BFD) is an extensive set of algorithms used to design BACCH filters with control over a large number of parameters (regularization, windowing, complex smoothing, pseudo inversion, XTC leakage, spectral flattening, etc.) The algorithms are coded in a single Mathematica notebook with an extensive GUI for interactive control of BACCH™ filter design procedure and optimization.

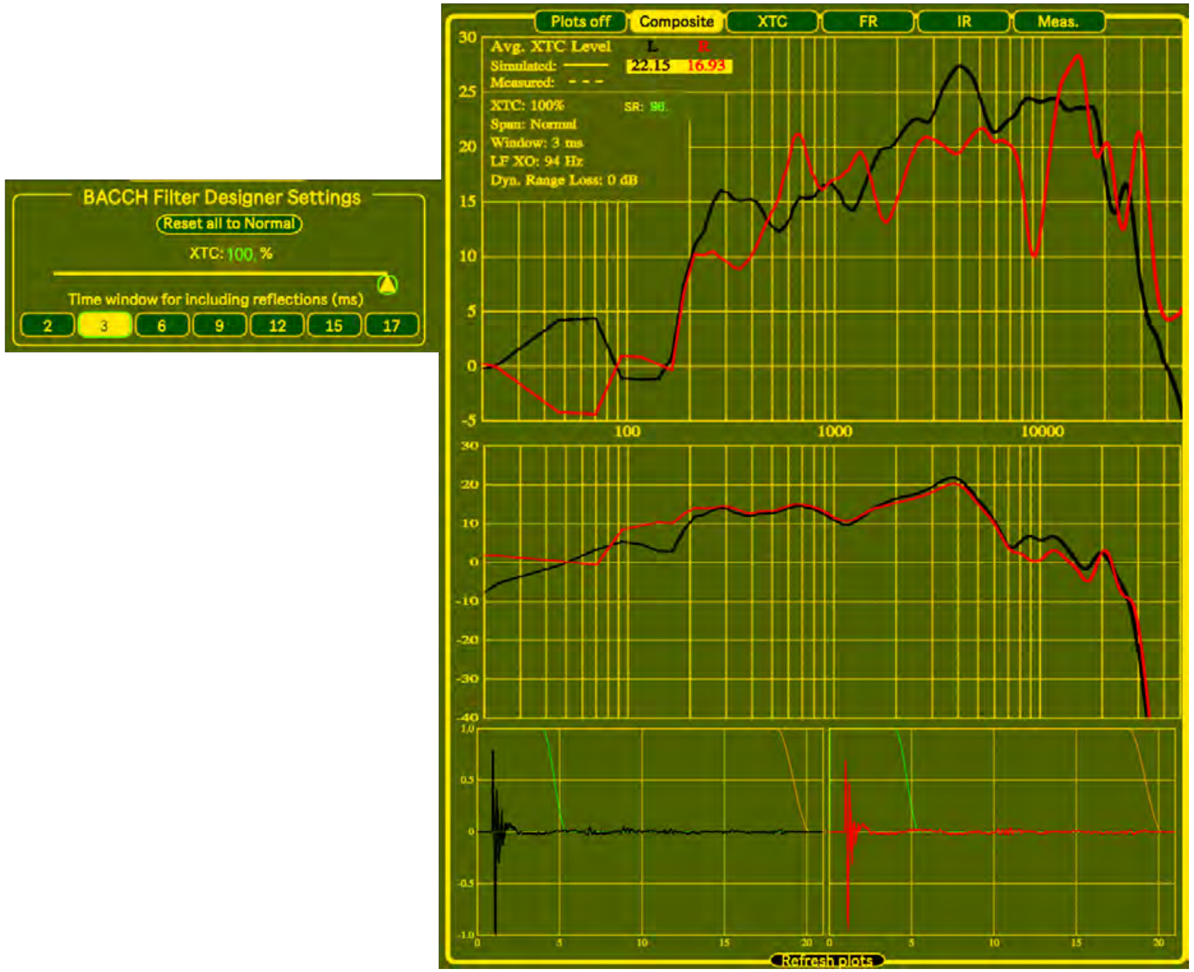
The BFD has been used to design BACCH™ filters for a number of commercial products including all three models of Jawbone's Jambox.



IP No.
12

ABFD
(Automatic BACCH™ Filter Designer)

Source: Theoretica
Type: Algorithm



Automatic Version of BFD

The ABFD is the automatic version of the BACCH™ Filter Designer described on the previous slide. It is implemented as a C++ code and works by detecting new impulse response measurements in a storage system and automatically processing those measurements into BACCH™ Filters after applying a pre-chosen set of design parameters.

The ABFD is central to all of Theoretica's products including the BACCH-SP (Grand, adio and dio) processors, and the BACCH-dSP application that is at the heart of the BACCH4Mac products.

It has been used by two automotive companies.

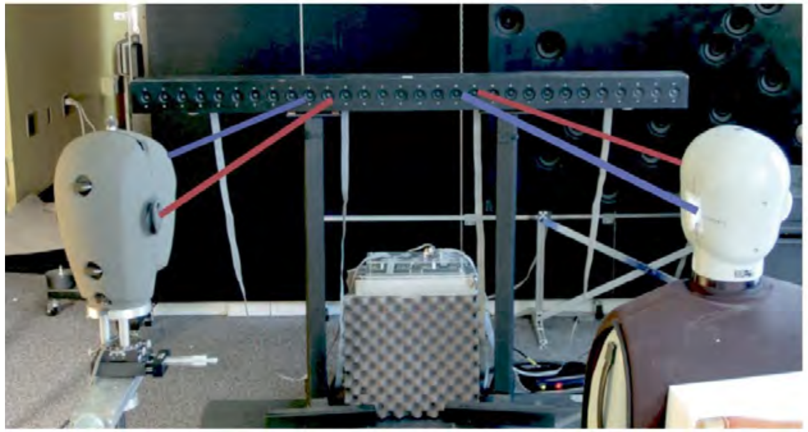
IP No. 13

BACCH-X

(Multiple Sweet Spot Audio Delivery Using Phase Array)

Source: Theoretica

Type: Algorithm



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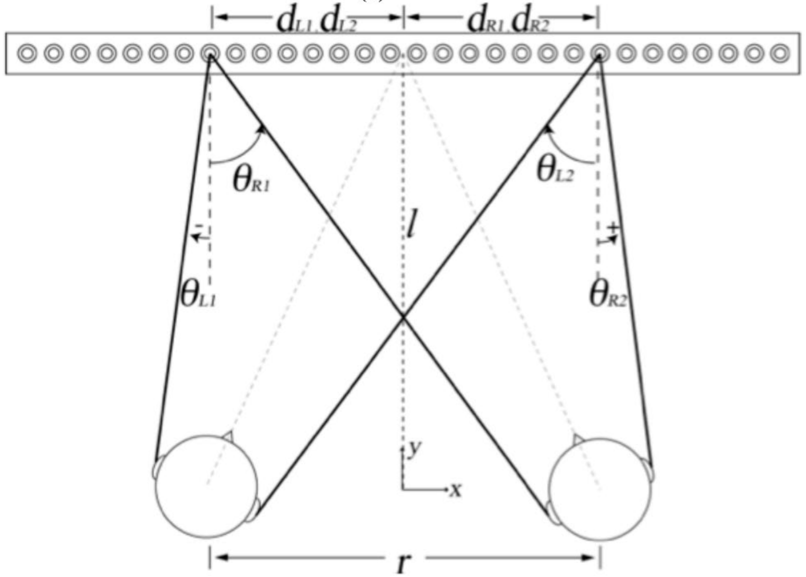


Beam Formation, Focusing and Steering Using Phased Arrays

BACCH-X is a series of algorithms that allow beam formation, collimation, apodization, windowing, focusing, and steering using phased arrays of transducers.

A BACCH-X controlled phased array generates multiple beams of sound (or more accurately "wedges" of sound in the case of a 1-D array, and actual collimated beams for the case of a 2D array), through precisely controlled constructive and destructive wave interference induced by assigning an appropriate delay to the input signal for each transducer. The phased array is capable of producing multiple highly directive acoustic beams that can be steered at any user-specified angle and focused to any user-specified point in front of it, thus creating multiple sweet spots.

The very high directivity of phased arrays is an important feature that enables a BACCH-X system to deliver audio to a listener with relatively little or no interactions with nearby walls or reflective surfaces. This ability of largely excluding the effects of room reflections through audio beaming and focusing makes BACCH-X particularly suitable for highly reflective and acoustically challenging listening environments.

BACCH-X can be used in conjunction with BACCH™ 3D Sound (IP#1) to deliver BACCH 3D audio to multiple listeners.

IP No. 14

BACCH-RHD

(**R**obust **H**ead-related Impulse Response **D**ensification)

Source: Theoretica

Type: Algorithm

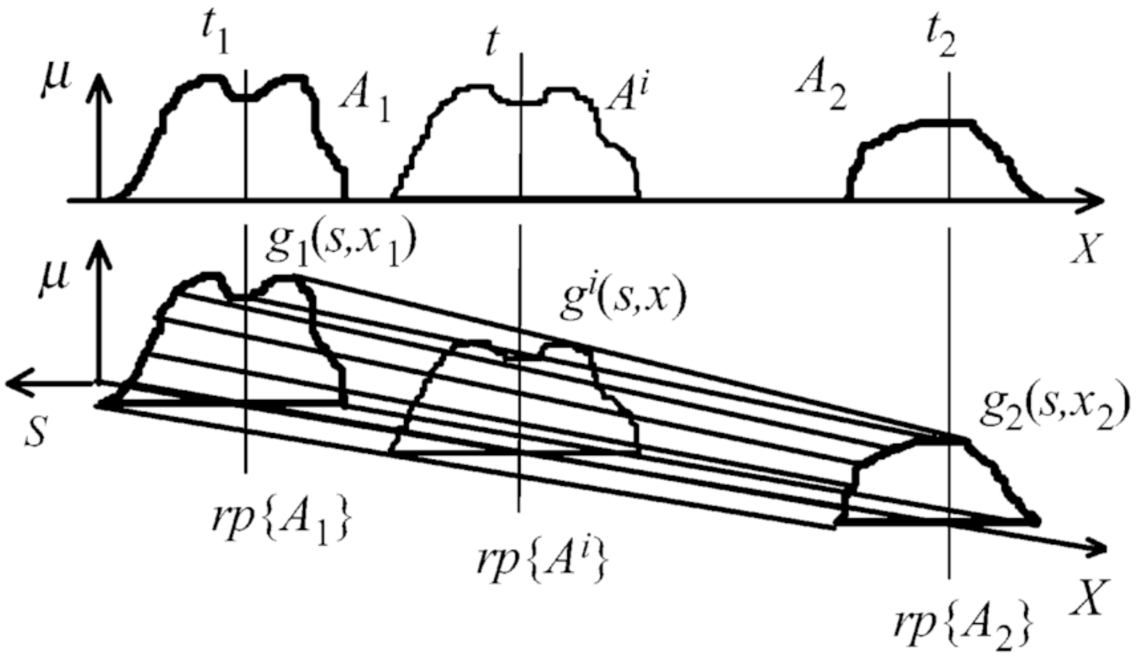
Algorithm for Robust Impulse Response Time-Alignment and Interpolation for HRIR Set Densification

Algorithm for ultra-robust HRIR and BRIR time-alignment and interpolation to produce a dense set of HRIRs from a sparse set of HRIR measurements.

For instance, BACCH-RHD takes a set of 3 BRIR measurements obtained at only the Center, extreme Left, and extreme Right positions of a desired extended sweet spot, and generates a bank of 41 FIR filters that allow dynamically adjusting the audio "sweet spot" as a function of listener's head position obtained from real-time head tracking.

The BACCH-RHD is used to generate the bank of BACCH™ filters needed for head-tracked crosstalk cancellation in all of Theoretica's products including the BACCH-SP (Grand, adio and dio) processors, and the BACCH-dSP application that is at the heart of the BACCH4Mac products.

It is also used in MAHHLER (IP#5).



IP No.
15

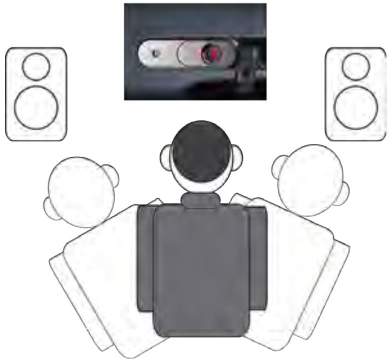
BACCH-ZfSC
(Zipper-noise-free Sliding Convolution)

Source: Theoretica
Type: Algorithm

Algorithm for Sliding Convolution between Adjacent FIRs without Zipper-Noise Artifacts

This algorithm uses advanced smoothing and fading techniques to allow real-time convolution to slide between adjacent FIRs without any audible artifacts such as zippering noise. Such sliding convolutions are key to head-tracked 3D audio.

The BACCH-ZfSC algorithm is the main ingredient in the **BACCHp plugin** (IP#35) and is also at the heart of all the convolvers used in BACCH Labs and Theoretica's products that rely on head tracking.



Rick Rubin leaning to the left. BACCH-ZfSC enables Rick to move laterally in the BACCH dynamic filter's sweet spot without any audible artifacts.

IP No.
16

.bac File Format

(Encrypted File Format for Proprietary FIR Filters)

Source: Theoretica
Type: Algorithm/File Format

A Highly Encrypted File Format for All FIR Filters Related to BACCH Technologies

The .bac format is a highly encrypted file format that relies on an advanced Linear Congruential Generator (LCG) to generate pseudo-random sequences that are used by a high-complexity cryptography algorithm to encrypt proprietary FIR filters.

BACCH Labs convolvers, including the BACCHp (IP#35) and BACCH-ZfSC plugins, load and quick decrypt .bac files.

```
LCG[seed_, a_, c_, m_, length_] := Module[{X, I, loop},
  X = Table[0, {length + 1}]; I = 2;
  X[[1]] = seed;
  Label[loop];
  X[[I]] = Mod[a X[[I - 1]] + c, m];
  If[(I = I + 1) ≤ length + 1, Goto[loop]];
  X = Drop[X, 1];
  X
 ]
```

IP No. 17

BACCH-HEQ

(**H**eadphones **E**qualization)

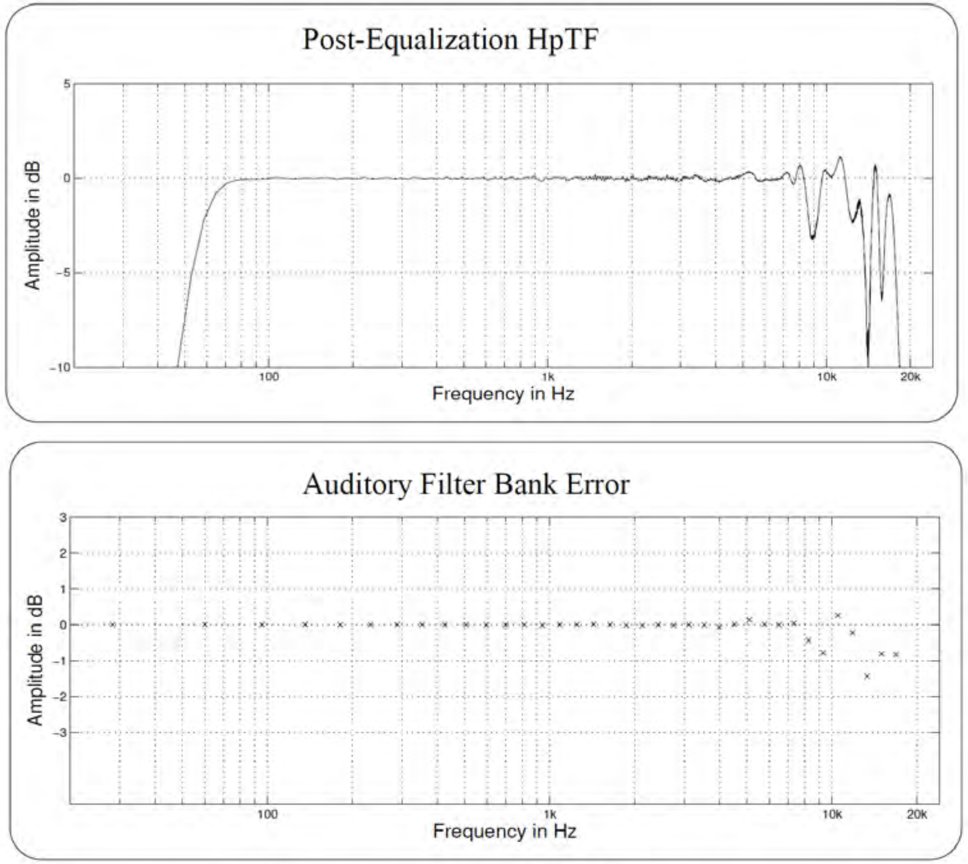
Source: Theoretica
Type: Algorithm

Algorithm for Headphones Equalization That Is Robust for Changes in Earcup Fitting

Advanced algorithm for headphones equalization based on measurements with in-ear binaural microphones.

Head externalization and tonal transparency of binaural audio through headphones can be severely compromised by the headphones response (especially for closed-back phones where the transducer-to-ear-canal impedance is high). BACCH-HEQ relies on a measurement of the HpIR with in-ear binaural microphones to produce an EQ filter that is robust for changes in ear cup fitting.

Implemented in the BACCH-SP (Grand, adio and dio) processors, and the BACCH-dSP application that is at the heart of the BACCH4Mac products.



The top panel shows a typical HpTF for a subject after equalization has been applied. Previously, the standard error measurement for this was based on a bank of *equivalent rectangular bandwidth* (ERB) filters that mimic the cochlea's auditory critical bands (bottom panel). The ERB error is the mean of the average error in each filter bank.

IP No. 18

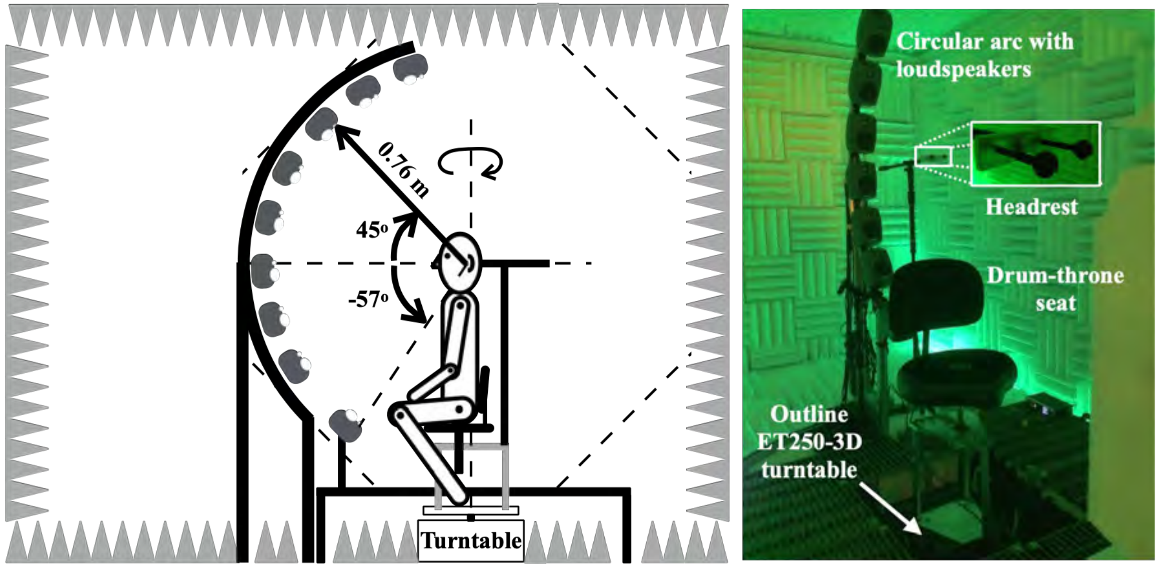
BACCH-HNfE
(HRTF Near-field Extension)

Source: Theoretica
Type: Algorithm

Algorithm for Extending HRTFs to the Near Field

Most HRTF's are measured at only one fixed distance, usually in the far field (> 1m) since below 1 m the HRTF changes quickly with distance. The BACCH-HNfE algorithm allows extending any HRTF to the near field for accurate reproduction of 3D audio objects with realistic proximity effects all the way down to distances of a few centimeters from the head.

This algorithm is an essential ingredient of the BACCH-3dm Mixer of the BACCH-dSP (IP#27) application.



3D3A Lab HRTF measurement set-up. Almost all HRTF's are measured in the far field. The BACCH-HNfE extends the HRTF to the near field and allows rendering of 3D audio objects with realistic proximity effects.

IP No.
19

BACCH-LyRE
(Listening Room Emulation)

Source: Theoretica
Type: Algorithm

Algorithm and GUI for Sampling a Listening Room and Rendering It Realistically through Headphones

The BACCH-LyRe algorithm allows measuring the impulse response of both the audio system and the listening room in which it resides from the perspective of an ideal listener and generates BACCH-LyRE filters that allow accurate emulation of that exact environment through headphones, or through a pair of speakers using a BACCH™ 3D Sound filter.

The BACCH-LyRE algorithm is the main ingredient in the BACCH-LyRE software in which a library of BACCH-LyRE filters corresponding to a library of pictures of specific audio systems in actual listening rooms (e.g. the studios of well-known engineers or audio critics) is available for the user to select from.

IP No.
20

BACCH-MCC
(Mono Component Correction)

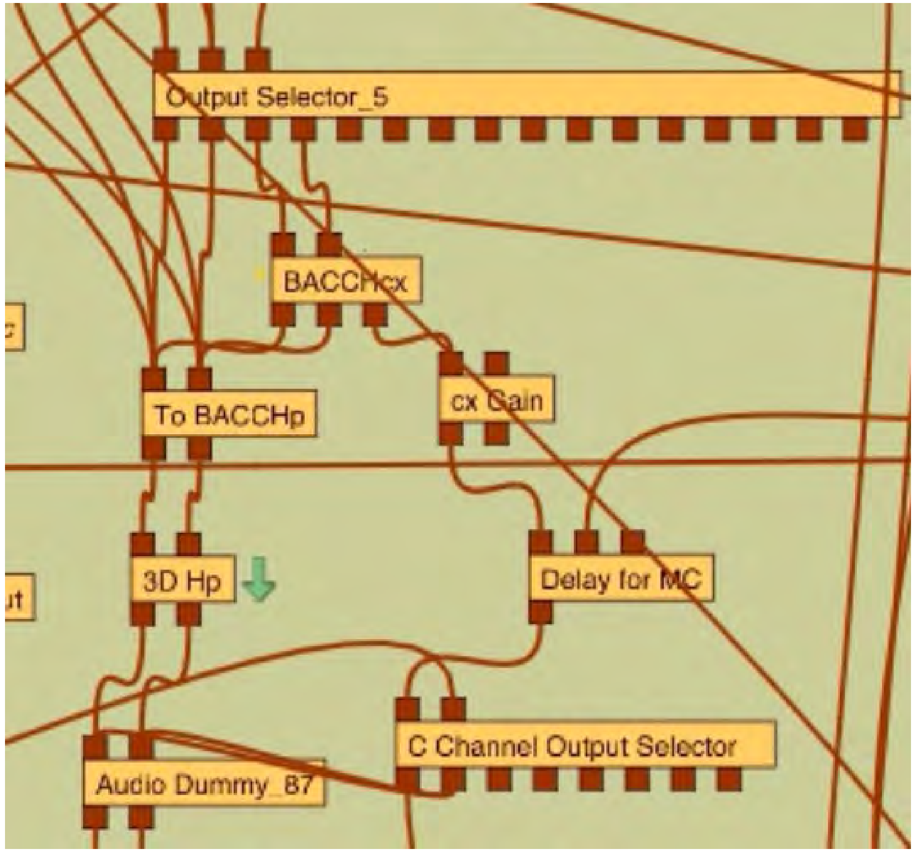
Source: Theoretica
Type: Algorithm

Algorithm for Restoring the Spectral Integrity of the Center Image in Crosstalk Cancellation with No Dynamic Range Loss

All crosstalk cancellation techniques, including BACCH™ 3D Sound have an inherent singularity for a mono input (or the highly-correlated component of a stereo input) which yields a spectrally colored center image, manifested as a bass rolloff that becomes more pronounced with decreasing speakers span. For small spans, such as the case for portable devices (e.g. mobile phones, portable speakers), the audible spectral coloration of the center image is significant and requires equalization and compression schemes that incur penalties such as reduced dynamics range (e.g. the Jambox).

The BACCH-MCC algorithm completely solves this problem, with no equalization, compression or dynamic range loss, by extracting the center channel using existing bit-perfect-reconstruction center-channel extraction algorithms, and appropriately delaying and mixing in the extracted center channel with the output of the crosstalk canceller.

BACCH-MCC is an essential ingredient in all of BACCH-Lab's implementations of BACCH™ 3D Sound.



IP No. 21

BACCH-DiFEQ
(Diffuse Field Equalization)

Source: Theoretica
Type: Algorithm

An Algorithm for Generating Optimal Diffuse Field Equalization Filters for Dummy (and Human) Head Microphones Used to Make Binaural Recordings That are Compatible with Both Speakers and Headphones Playback

Binaural recordings done with dummy or human heads sound tonally colored when played over loudspeakers, thus the warning on binaural recordings to "playback on headphones only". This coloration is due to the tonal signature of the torso, head and pinnae of the binaural microphone. Equalizing these tonal signatures too much would lead to a loss of the binaural cues, which compromises the fidelity of the spatial reproduction. Equalizing them too little makes the audio incompatible with playback on speakers.

The BACCH-DiFEQ algorithm allows the derivation of optimal diffuse field equalization from acoustic measurements done in a regular room, without the effort and expense of making detailed HRTF measurements in an anechoic chamber, or diffuse field response in a reverb chamber (which were the standard methods to derive DiFEQ filters).

Five generations of BACCH-DiFEQ filters were used to equalize all 41 albums of the Binaural+ Series by the premier audiophile record label Chesky Records. Two of these albums won the coveted Record of the Month award by Stereophile magazine.

IP No.
22

BACCH-BMC

(Binaural Microphone Calibration)

Source: Theoretica
Type: Algorithm

Algorithm for Deriving Optimal Free-Field Equalization Filters for In-Ear Binaural Microphones with Minimum Dynamic Range Loss

While electrets are ideal for use as the capsules of in-ear binaural microphones, the capsules of even a “matched pair” of electrets have un-matched and non-flat frequency response. The BACCH-BMC algorithm uses acoustic measurements in a semi-anechoic enclosure and a reference microphone to derive gain-compensated free-field equalization that matches and flattens the response to within a small fraction of 1 dB, while minimizing the dynamic range loss.

The BACCH-BMC algorithm is used to provide equalization filters for the more than 200 BACCH-BM and BACCH-BM Pro (IP#60) used around the world by audiophiles, pro audio professionals, university researchers and companies including NYU, U of Rochester, American Univ, Volkswagen, Tesla, Focal, Chamber Music Society at Lincoln Center, and Chesky Records.

IP No. 23

u-BACCH

(Universal BACCH™ Filter)

Source: Theoretica
Type: Algorithm

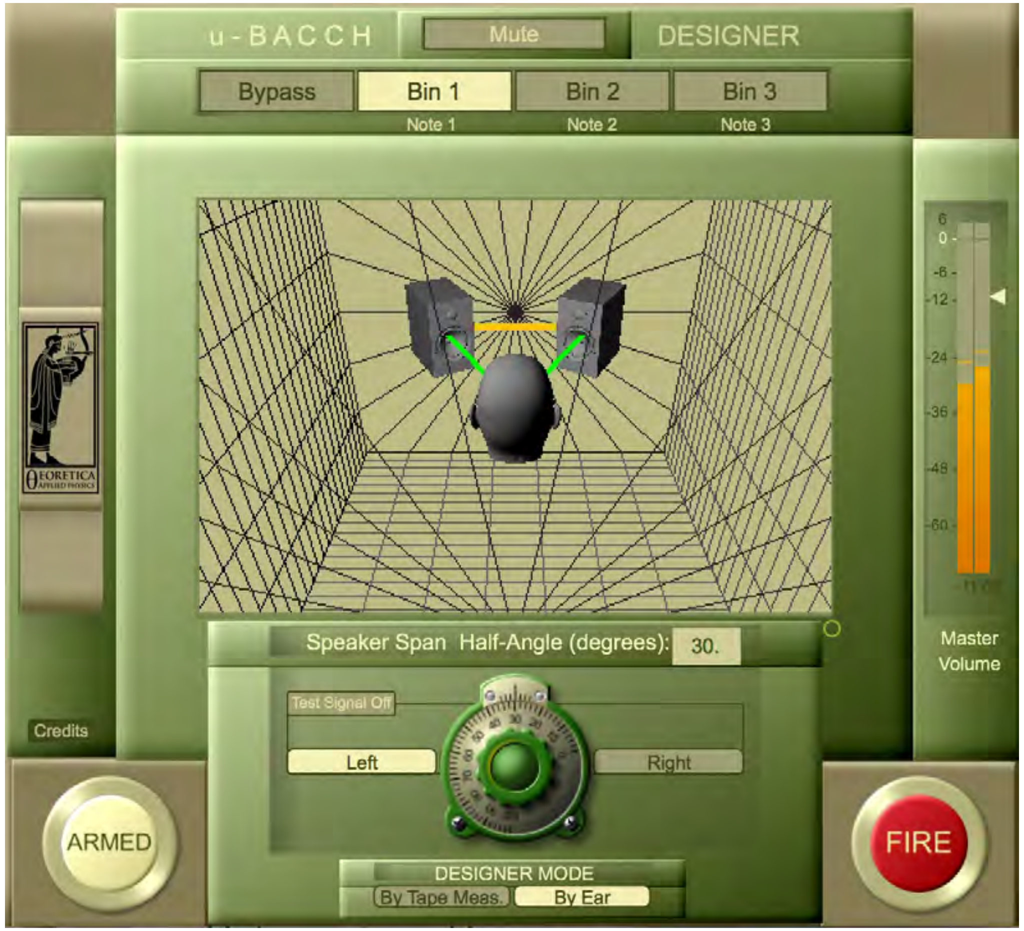
Algorithm for Obtaining a BACCH™ 3D Sound Filter with No Acoustic Measurement

The u-BACCH algorithm allows obtaining the optimal BACCH™ 3D Sound Filter for a given listening configuration, without relying on acoustic measurements.

In Mode I, the u-BACCH algorithm derives a BACCH™ 3D from a set of pre-stored filters based on measured distances between the speakers and the listener.

In Mode II, he u-BACCH algorithm relies on the Zipper-noise-free Sliding Convolution algorithm, BACCH-ZfSC (IP#15), to allow the listener to adjust the filter selection in real time to maximize the perceived crosstalk cancellation.

This algorithm is the essential ingredient of the u-BACCH Designer module of the BACCH-dSP application (IP#34) and is used in the BACCH-AHI (IP#36) application for Mac and Windows as is available to any application that uses an SDK incorporating the BACCH Core Library (IP#39).



IP No. 24

BACCH-HTap
(Head-Tracked Audio Processor)

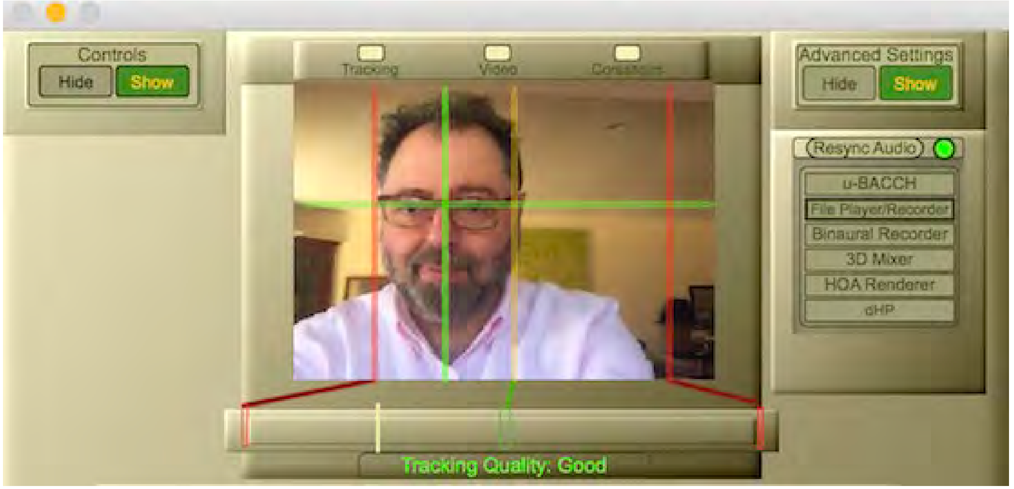
Source: Theoretica
Type: Algorithm

Algorithm for Setting Up and Executing Audio Processing That Evolves as a Function of Head Position

BACCH-HTap is a multi-task algorithm that allows for

1) Setting up the head tracking range of a head tracker through a calibration protocol involving the use of video feedback and audio instructions for the listener to move his/her head to the three positions defining the center, and left and right limits of the head tracking range.
2) The triggering of exponential sine sweeps at these locations to obtain the required IRs through acoustic measurements with in-ear microphones.
3) The automatic generation of a dense bank of IRs using the BACCH-RHD IR densification algorithm (IP#14).
4) The control of sliding convolutions through the BACCH-ZfSC algorithm as a function of the real-time head coordinates obtained from any head tracker.
5) The real-time visual feedback of the head-tracked sliding convolution.

BACCH-HTap has been implemented in various BACCH Labs and Theoretica products using various third-party head tracking SDKs including Visage's FACE TRACK, NaturalPoint's TrackIR and other IMU and IR head trackers.



IP No.
25

BACCH-HTRC
(Head-Tracked Room Correction)

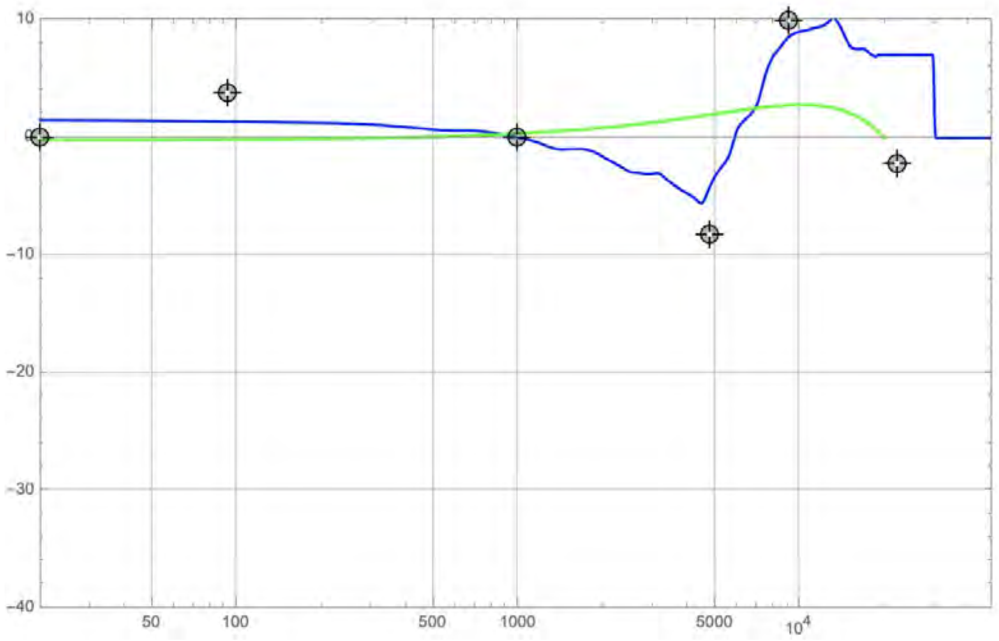
Source: Theoretica
Type: Algorithm

Algorithm for Providing Room Correction as a Function of Real-Time Head Position

BACCH-HTRC is the main algorithm that enables the world's first room correction system that provides target curve equalization as a function of real-time head position.

BACCH-HTRC has the same functionality as the BACCH-HTap algorithm (IP#24) but in addition

1) Extracts an out-of-ear room impulse response (OERIR) from a binaural room impulse response (BRIR) measured with in-ear microphones by applying advanced frequency-dependent smoothing that effectively removes the transfer function of the head.
2) Derives a set of 3 Room Correction (RC) FIR filters that match a desired target response curve at the three positions defining the center, and left and right limits of the head tracking range.
3) Generates a dense bank of Room Correction EQ IRs using the BACCH-RHD IR densification algorithm (IP#14).
4) Controls the Room Correction convolutions through the BACCH-ZfSC algorithm as a function of the real-time head coordinates obtained from any head tracker.

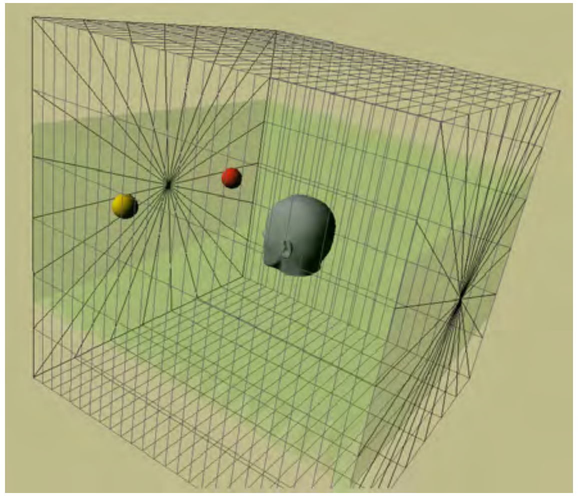


The Blue curve is the out-of-ear room impulse response (OERIR) extracted from a measured binaural room impulse response (BRIR) by the BACCH-HTRC algorithm. The algorithm then generates a room correction (RC) FIR filter that causes the room response to match the target response curve shown in green.

IP No. 26

BACCH-VLS
(Virtual Loudspeakers)

Source: Theoretica
Type: Algorithm



Algorithm Using Virtual Loudspeakers in a Virtual Room with Simulated Controllable Early Reflections and Reverb to Design BACCH™ 3D Sound and BACCH-HP Filters without Acoustical Measurements

The BACCH-VLS is implemented as a designer Mode in BACCH-dSP's 3dm mixer. It allows designing BACCH™ 3D Sound and BACCH-HP filters under ideal and controllable acoustics using point sources as virtual loudspeakers using any desired HRTF stored in the SOFA format. Such filters are more universal, i.e. they have better performance on average than filters done in real rooms and real speakers, when used in various environments that are not known a priori.

BACCH-VLS can also be used to study how the performance of BACCH™ 3D Sound and BACCH-HP filters depend on early reflections, reverb and the size of the listening room and the location of listeners and speakers within it.

The Dell XPS 17 "fights" the BACCH filter measurement process because of both the Multibanded Compressors in the "Smart" Power Amplifiers and the reflections off of the non-deterministic screen hinge angle. For this device the BACCH-SP Filter made with the VLS Filter Design process is both high quality and greatly outperforms the measured filter.

IP No. 27

BACCH-3dm
(3D Mixer)

Source: Theoretica
Type: Algorithm

A Set of Algorithms for Producing Realistic Binaural Mixes (Equivalent to Binaural Recordings Produced through Dummy Heads or humans with In-Ear Microphones) from a Collection of Multiple Audio Sources Such as the Tracks of a Multi-Track Recording

The BACCH-3dm algorithms are implemented in the 3dm module of the BACCH-dSP application. They provide a large number of functions and features including the following:

1) A visually intuitive graphical interface that allows positioning multiple sound sources (each corresponding to a bus line from your DAW, a microphone signal, an audio file or a track from a multi-track file) precisely in 3D space.
2) A large library of human and dummy head HRTFs and ability to load individualized HRTFs with conversion from the regular SOFA format.
3) Accurate real-time early reflections and reverb calculations based on user-controlled room geometry and a wide range of wall materials.
4) Real-time six-degrees-of-freedom (X, Y, Z, Pitch, Yaw and Roll) navigation of the 3D sound field using the keyboard a Playstation controller or the BACCH-HT-NAV algorithm (IP#29)
5) Ability to automate the motion of sound sources along prescribed 3D trajectories designed with the BACCH-TRJ algorithm (IP#28).
6) Full automation capability and syncing with most existing DAWs.
7) Presets for down-mixing multi-channel Surrond Sound (e.g. decoded Dolby or DTS) for various speaker configurations (5.1, 7.1, Dolby Atmos 5.1.4 and 7.1.4,and Auro 3D 11.1) to binaural audio for Surround Sound emulation over headphones or two loudspeakers.

IP No. 28

BACCH-TRJ
(3D **Trajectory** designer)

Source: Theoretica
Type: Algorithm

A Suite of Algorithms That Allow the Design of Complex Trajectories for Animating the Motion of Virtual Sound Sources in 3D Space

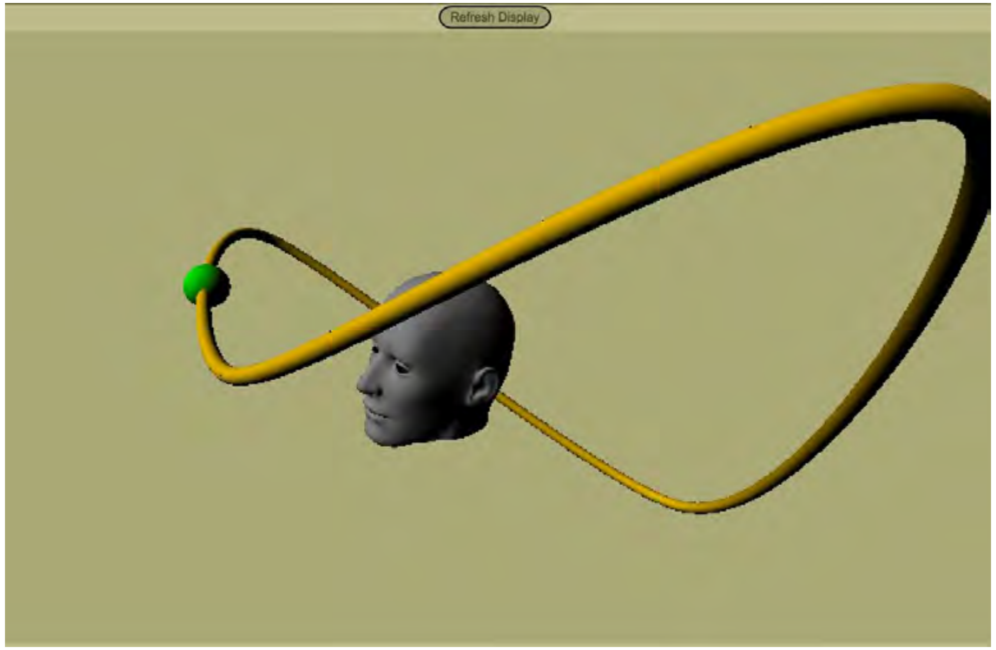
The BACCH-TRJ algorithms are implemented in the TRJ module of the BACCH-dSP application. They provide functions and features that include the following:

1. An easy-to-use and intuitive interface allows drawing simple or complex 3D trajectories in the 3dm mixer by hand or by precise 3D positioning of anchor points on the trajectory.

2. The speed of each source as it moves on a given 3D trajectory can be precisely controlled and the motion can be automated.

3. Automation of the motion of any of the 20 sources along drawn trajectories can be transmitted to any of the leading DAWs (e.g. ProTools, Logic Pro, Ableton Live), where it can be recorded, edited, and sent back to the 3dm mixer for playback.

4. Even the head of the "listener" can be made to move along a 3D trajectory, and its six degrees of freedom (x,y,z, pitch, yaw and roll) can be automated from the DAW.



IP No.
29

BACCH-HT-Nav
(Head-tracked Navigation)

Source: Theoretica
Type: Algorithm

Algorithm for 6 DOF Navigation of 3D Sound Field Using Head Tracking

The BACCH-HT-Nav algorithm are implemented in the HT-Nav module of the BACCH-dSP application. It provides functions and features that include the following:

1. Accurate real-time navigation of 3D sound fields by simple movements of the user's head in 6 DOF.

2. Motion amplification (or attenuation) by up to x2 in any of the 6 DOF.

IP No. 30

BACCH-HOA
(Higher Order Ambisonics)

Source: Theoretica
Type: Algorithm

A Suite of Algorithms That Allow Up-To-Fourth-Order High-Order-Ambisonics-to-Binaural Rendering and 3D Sound Field Navigation Using Up to 20-Speaker Full Dodecahedron Virtual Speaker System and Individualized HRTFs

The BACCH-HOA algorithms are implemented in the HOA module of the BACCH-dSP application. They provide functions and features that include the following:

1. Support for HOA mics with up to 32 capsules (e.g. the em-32 Eigenmike)

2. Up-to-4th-order ambisonics decoding to uniform virtual loudspeaker spherical arrays.

3. Binaural rendering with individualized HRTFs and 6-degree-of-freedom navigation of the rendered 3D soundfield.

4. Real-time six-degrees-of-freedom (X, Y, Z, Pitch, Yaw and Roll) navigation of the 3D sound field using the keyboard, a Playstation controller or the BACCH-HT-NAV algorithm (IP#29)

IP No.
31

BACCH-hs^3
(Head-Steered Sound Spotlight)

Source: Theoretica
Type: Algorithm

A Suite of Algorithms That Relies on HOA to Create a "High-Order Beam" That Can Be Steered Anywhere in 3D Space Using the BACCH-HT-Nav (IP#29) by Simply Looking in That Direction, to Significantly Isolate Sound Sources in the Beam from the Background

The BACCH-hs^3 algorithms are implemented in the hs^3 module of the BACCH-dSP application. They provide functions and features that include the following:

1. Selectable HOA beam pattern, up to 4-th order hypercardiod, that allows up to 14 dB isolation from the background.

2. Accurate 3D head-tracked steering using the BACCH-HT-Nav algorithm (IP#29).

3. Low-latency binaural rendering in 3D through noise cancellation headphones or earphones.

IP No. 32

BACCH-sme
(Stereo Mic Emulation)

Source: Theoretica
Type: Algorithm

Algorithms for the Accurate Emulation of a Variable-Pattern Pair of Stereo Mics for Recording (or Low-Latency Live Monitoring) Using a Single HOA Mic

The BACCH-sm2 algorithms are implemented in the same module of the BACCH-dSP application. They provide functions and features that include the following:

1) 14 selectable beam patterns (omni, and 1st, 2nd, 3rd and 4th-order cardioid, supercardioid, and hypercardiod), for each mic in the stereo pair.

2) Beam steering in 3D, manually or through the BACCH-HT-Nav algorithm (IP#29) using virtually any regular webcam or infrared Track IR headtracking hardware.

3) Presets for emulation of "XY", Blumlein, and "MS" stereo pair of microphones.

IP No.
33

BACCH-BM Pro
(in-ear Binaural Microphone)

Source: Theoretica
Type: Algorithm

State-of-the-Art In-Ear Binaural Microphone with Proprietary Capsules and Circuitry with Individual Free-Field Equalization for an Ultra-Flat Response Up to 30 kHz and Record SNR for Its Size

Using an ASIC amplifier, which provides high ESD and RFI tolerance as well as consistent biasing characteristics compared to single FET amplifiers, the BACCH-BM Pro has the highest signal-to-noise ratio, sensitivity, and frequency extension of any microphone its size.

IP No.
34

BACCH-dSP
(desktop Signal Processor)

Source: Theoretica
Type: Software

BACCH-dSP is a Standalone 3D Audio Powerhouse Application for the Mac for Mixing/Production and Rendering of 3D Binaural Audio through Loudspeakers and Headphones

It is the most advanced binaural audio processing tool available today. It incorporates many techniques, algorithms, and methods that come out of the research at the 3D3A Lab and Theoretica. Among many functions, and capabilities, it allows for the construction and rendering of stereo 3D audio images with breathtaking realism.

BACCH-dSP contains more than a dozen of modules that feature many of the algorithms described in this deck. It is used by pro audio professionals, university researchers and companies including NYU, U of Rochester, American Univ., leading automakers, leading high-end audio companies, and leading Internet platforms.

IP No.
35

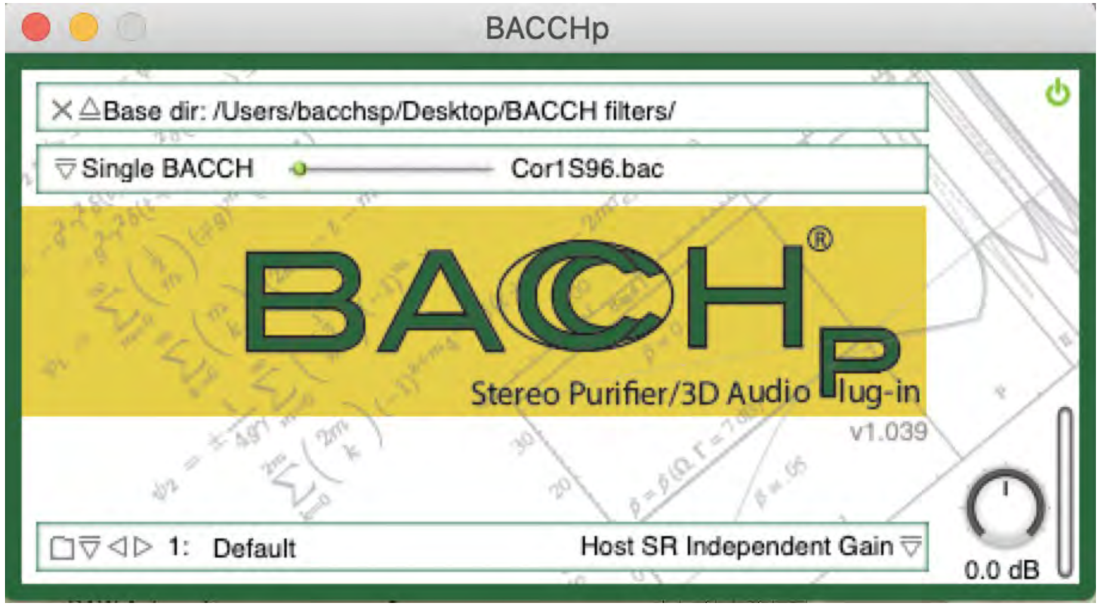
BACCHp
(Sliding Convolver Plugin)

Source: Theoretica
Type: Software

Plugin for True Stereo Sliding Partitioned Convolution from a Large Bank of Filters in the .bac Format

The BACCHp is a VST and AU plugin that uses fast partitioned 2x2 (true stereo) convolution that relies on the BACCH-ZfSC algorithm (IP#15) to slide between FIR filters in the .bac format (IP#16) stored in a bank containing up to 2048 filters.

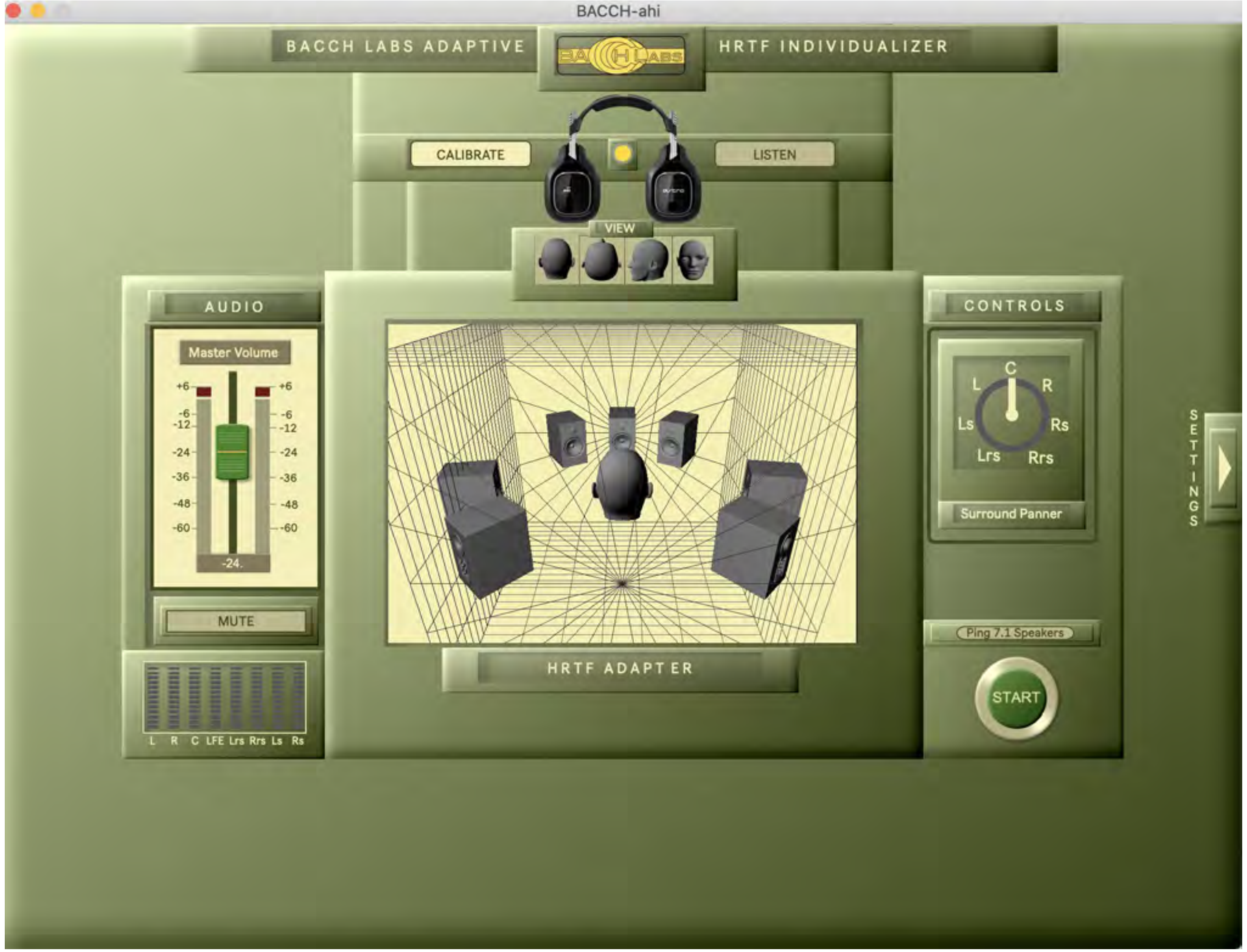
BACCHp has also be been re-written as a VST3 plugin (called BACCH-XTC) by BACCH Labs and the algorithm was ported to all of BACCH Lab's implementations of convolvers used with head tracking.



IP No.
36

BACCH-AHI
(Adaptive HRTF Individualizer application)

Source: BACCH Labs
Type: Software



Standalone Application for Mac and Windows OS That Implements the BACCH-AHI Patent-Pending Method

The BACCH-AHI application for Mac and Windows is an implementation of the patent-pending method (IP#6), which is a robust technique for obtaining filters that individualize 3D audio rendering over headphones to insure head externalization of sound by relying on a simple calibration procedure by the listener. The calibration relies on the listener's feedback on the perceived locations of specific sound sources as the system composes a composite individualized HRTF from a large database of especially selected and serialized HRTFs.

IP No.
37

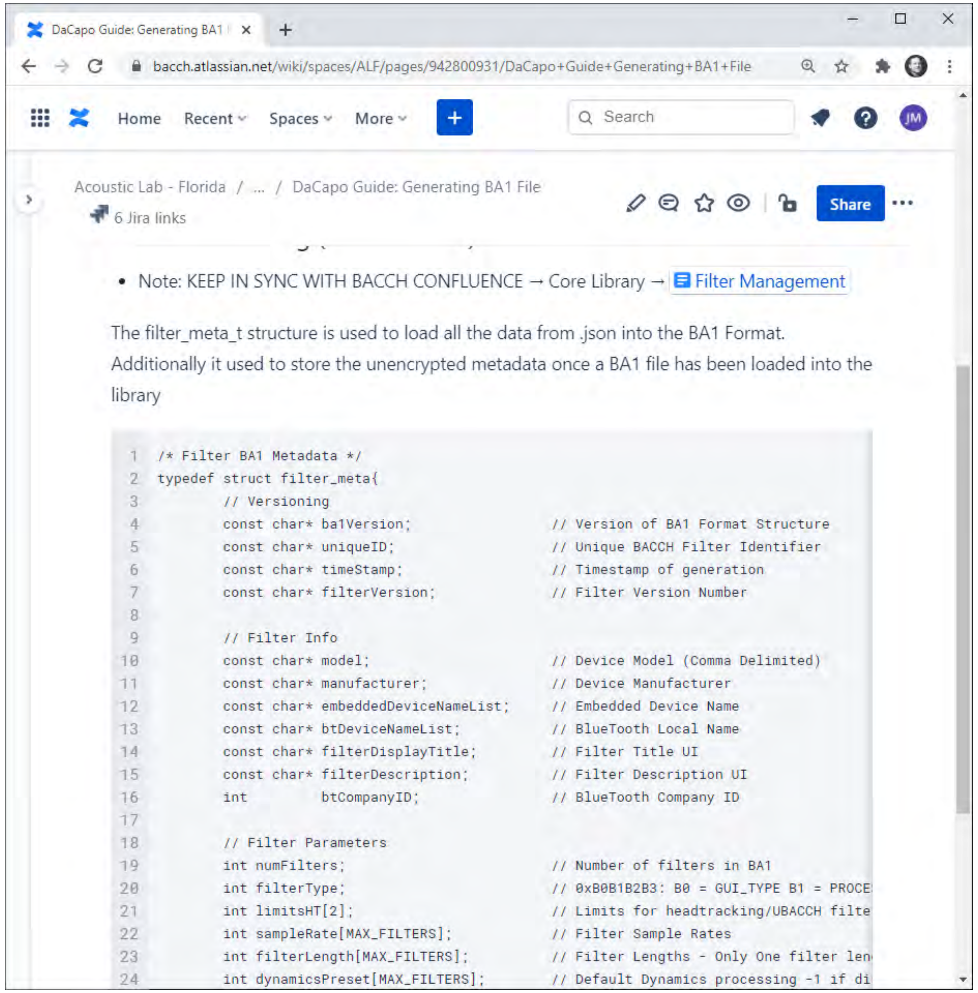
BACCH Ba1 Format

Source: BACCH Labs
Type: Software

The Ba1 File Format Defines a Container with All of the Information to Perform BACCH 3D Rendering in a Particular Device

Ba1 Support includes:

- Metadata to define a particular device, family of devices, or LyRE emulated listening room.
- Support for multiple filters, such as a headphone filter and a speaker filter for the same device
- BACCH filters as generated by the BACCH-dSP (.bac files)
- Additional information about the filter structure, including the use of compressors and compressor settings, enabling the equivalent of a complete patch with a different signal flow for each filter
- Metadata population for each Device Under Test is done using a PDF form which generates a JSON file to enable the generation of a ba1 file.
- SHA 256 Encryption



BACCH LABS

IP No.
38

BACCH Device Library

Source: BACCH Labs
Type: Software

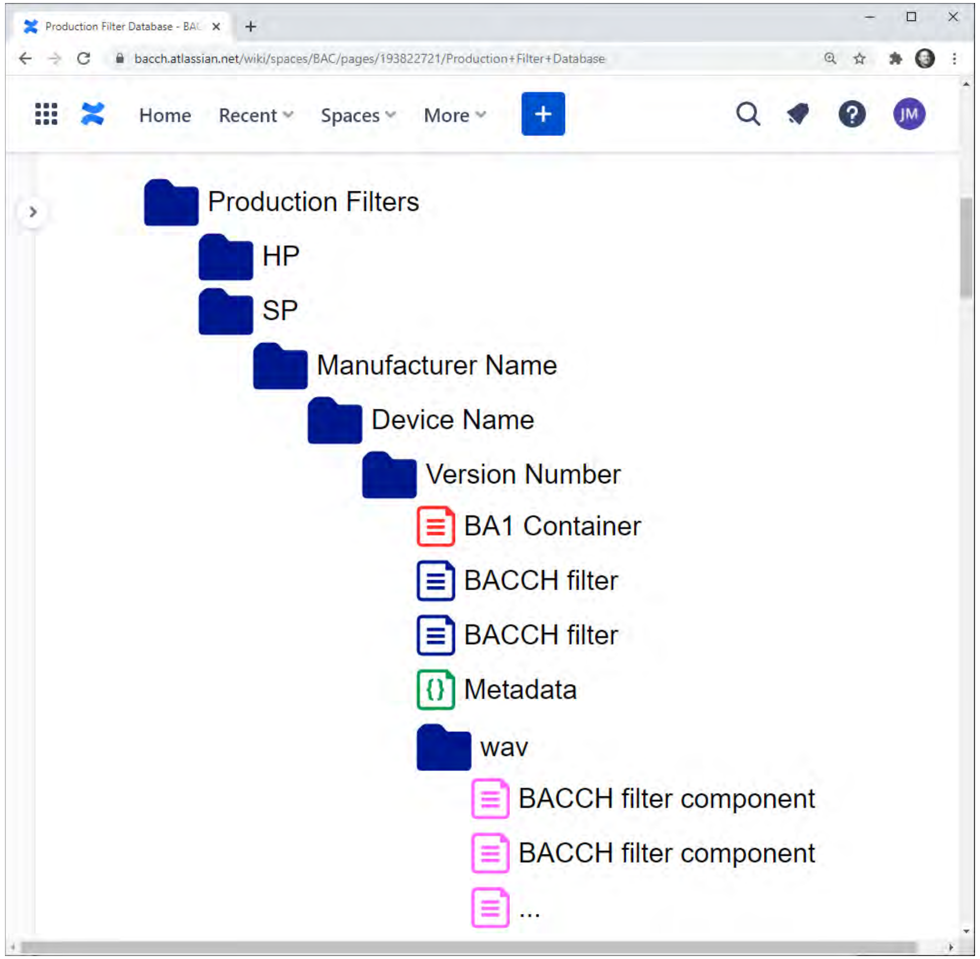
BACCH Device Library

The BACCH Device Library consists of two sections.

The Production Filter Database contains a list of filters that have been Released To Production.

The internal Library contains additional filters that are not Released To Production.

The Production Filter Database also supports the concept of an Unsupported Device. In other words, the Production Filter Database can be used to identify that a device has been tested and does NOT support any BACCH filters, such as a mono device.



IP No.
39

BACCH Core Library

Source: BACCH Labs
Type: Software

A Monolithic-to-the-Customer Library That Supports Processing All Possible Signal Flows Requested by Ba1 File

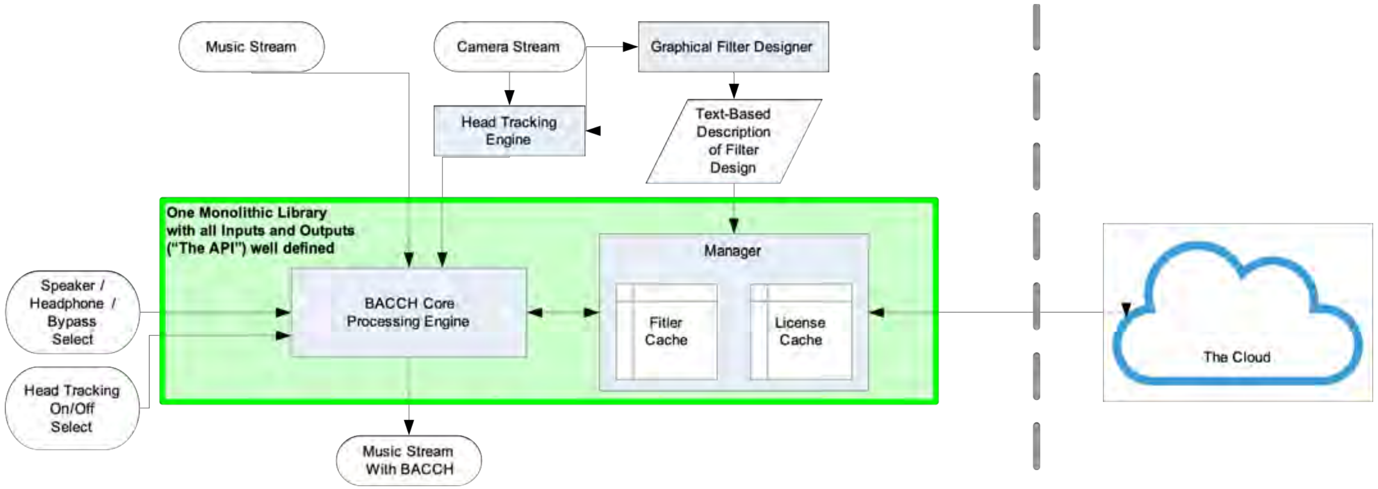
Functions include:

- BACCH-SP filters
- BACCH-HP filters
- Compressors, including multiple stages and EQ filters
- Input from head trackers

The BACCH Core Library accepts PCM-style (raw) audio stream including

- Multiple sampling rates
- Multiple bit depths
- Multiple block sizes

The BACCH Core Library is written in native C/C++ and supports platform specific acceleration libraries, including Intel Performance Primitives (IPP) and ARM(Neon).



IP No. 40

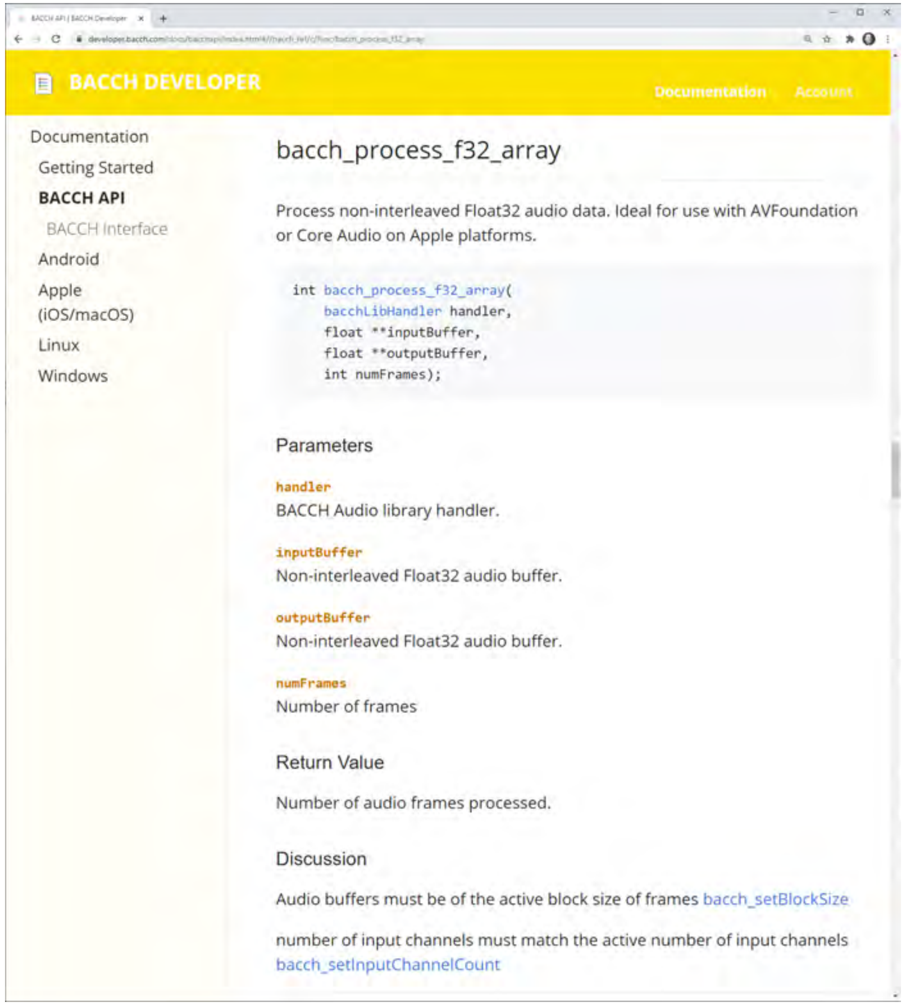
BACCH API

Source: BACCH Labs
Type: Software

The Application Programming Interface to the BACCH Core Library

A complete C language API.

Kept up-to-date for our customers here. Login Credentials available.
https://developer.bacch.com/



IP No.
41

Compressor

Source: BACCH Labs
Type: Software

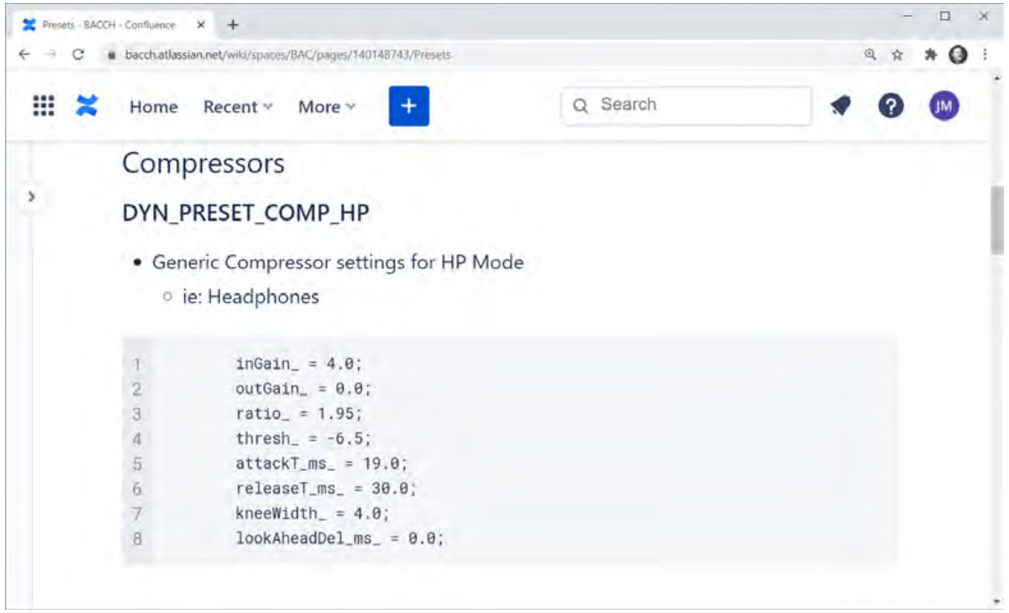
A collection of single-band and multi-band compressors

Primary uses:

- Compensate for the dynamic range loss of certain Virtual Loud Speaker filters
- Generate parity when A/B Testing against other compressed audio chains. May be cascaded.
- Supports closely related functions including limiters

Features include:

- Plug-In instantiation with Graphical User Interface for tuning
- Programmatic interface with ability to create new presets based on GUI tuning.
- Extensive set of know-how and documentation on how to use compression, especially with small, unbalanced devices and smartphones.



IP No. 42

S-BACCH (Software-as-a-Service BACCH)

Source: BACCH Labs
Type: Software

Software-as-a-Service BACCH (S-BACCH) Enables Any Internet Connected Software Incorporating BACCH to Check in with Licensing Server, Media Server, and Device Library Server

The licensing servers enable

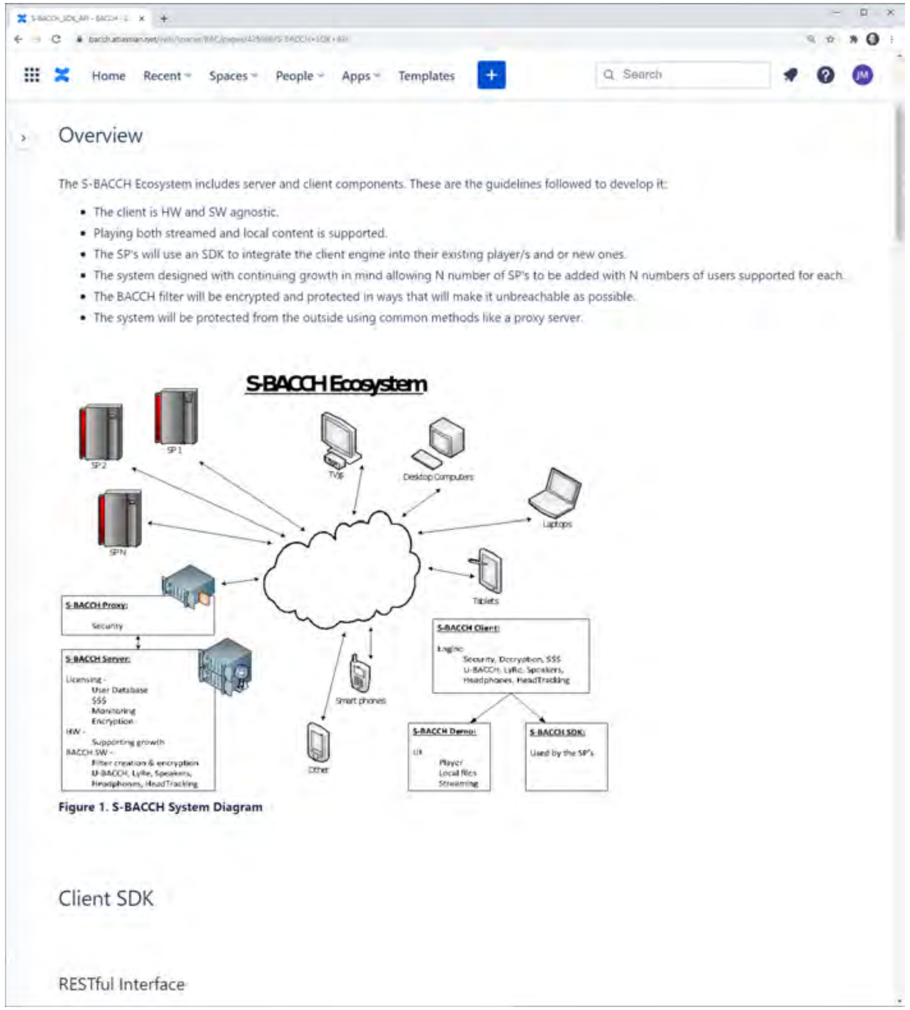
- A one-time-purchase to enable a specific client indefinitely
- Free trials
- Subscription plans
- Additional license as customers scale clients and devices
- Automatic license accounting and customer audit reports

The Media Servers enable

- A fast method of pushing demo and promo content

The Device Library Server servers enable

- Client devices can search for devices in the Production Filter Database
- Metrics to track frequently requested devices to add to the Filter Database
- LyRE Filters as in In-App-Purchase and other (paid) DownLoadable Content



IP No.
43

BACCH4Kalimba

Source: BACCH Labs
Type: Software

An Implementation of the BACCH Core Library for the Kalimba DSP Used in Bluetooth Chipsets

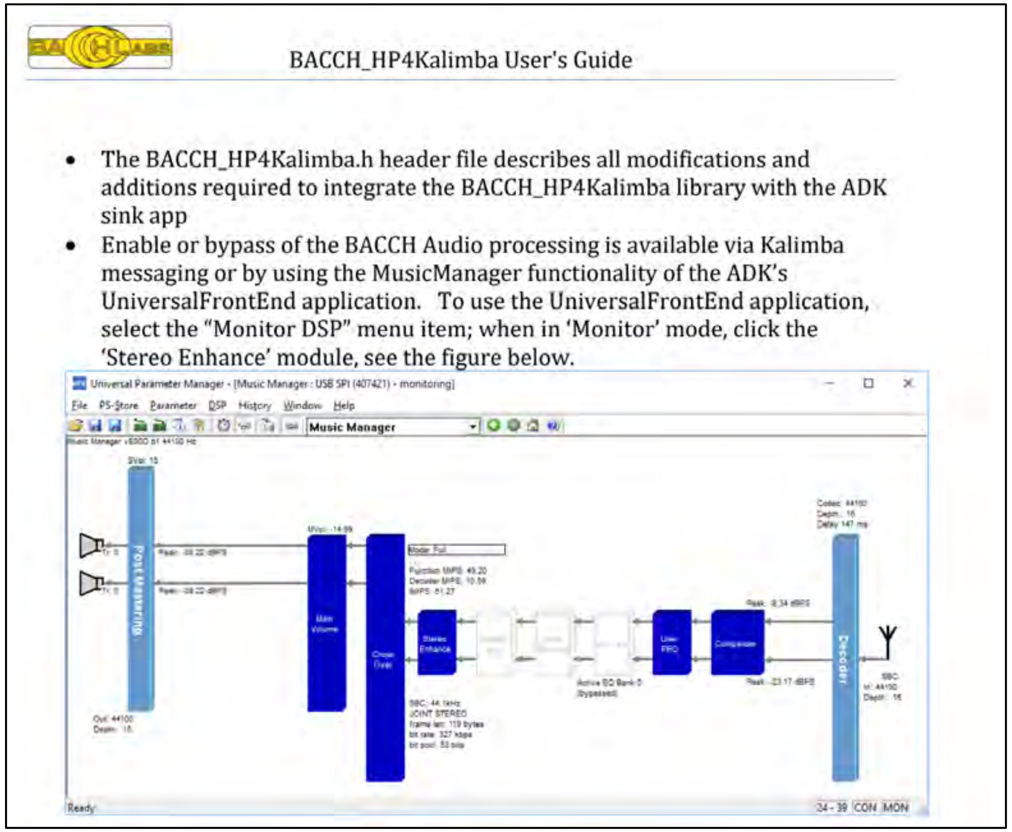
Hand-optimized assembler library
Automatic setup script
96 kHz support
demo app

Filter Support: BACCH-SP, BACCH-HP

CSR Chipsets: CSR 8670 / 8675

CSR is now part of Qualcomm. Additional Qualcomm Kalimba chipsets supported:
Qualcomm QCC 5124 / 5100 Series

BACCH Labs is a Qualcomm Advantage Network registered Independent Software Vendor (ISV).

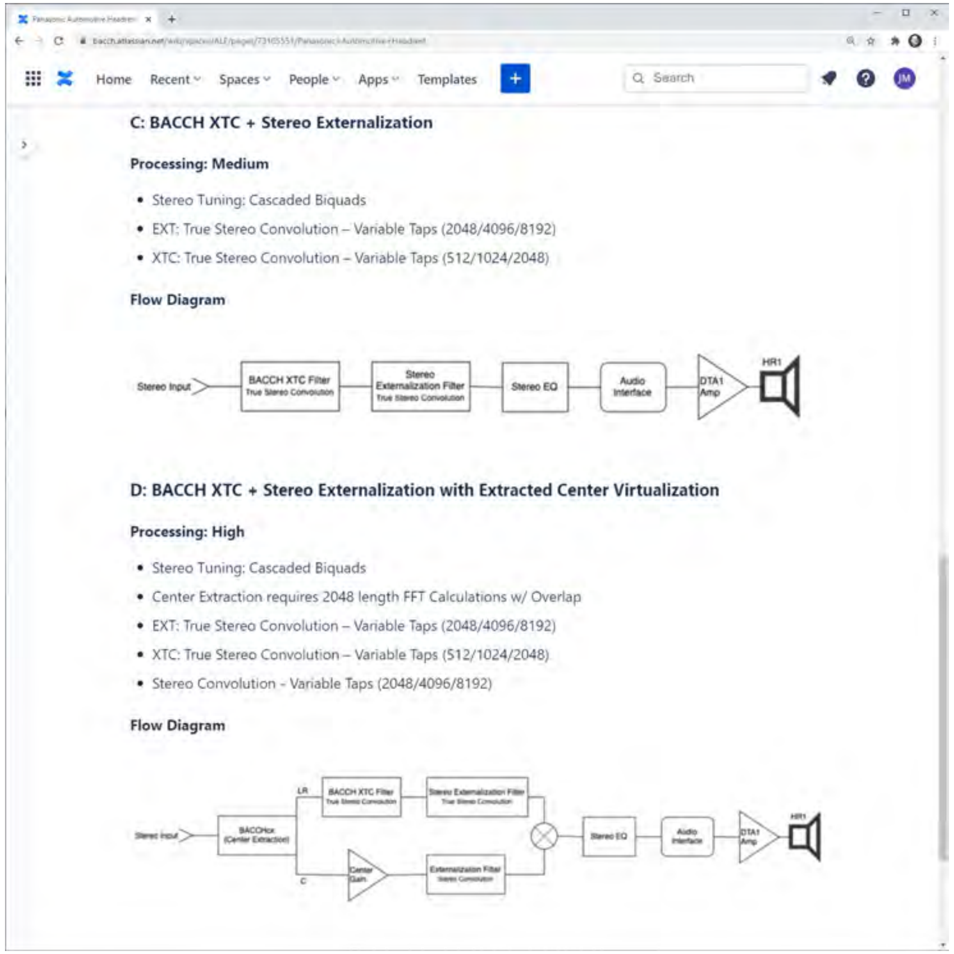

BACCH_HP4Kalimba User's Guide

- The BACCH_HP4Kalimba.h header file describes all modifications and additions required to integrate the BACCH_HP4Kalimba library with the ADK sink app
- Enable or bypass of the BACCH Audio processing is available via Kalimba messaging or by using the MusicManager functionality of the ADK's UniversalFrontEnd application. To use the UniversalFrontEnd application, select the "Monitor DSP" menu item; when in 'Monitor' mode, click the 'Stereo Enhance' module, see the figure below.

IP No. 44

BACCH4ADAU

Source: BACCH Labs
Type: Software



An Implementation of the BACCH Core Library for Analog Devices ADAP DSPs Popular in Many Consumer and Automotive Audio Devices

Hand-optimized assembler library
Integration with Sigma Studio

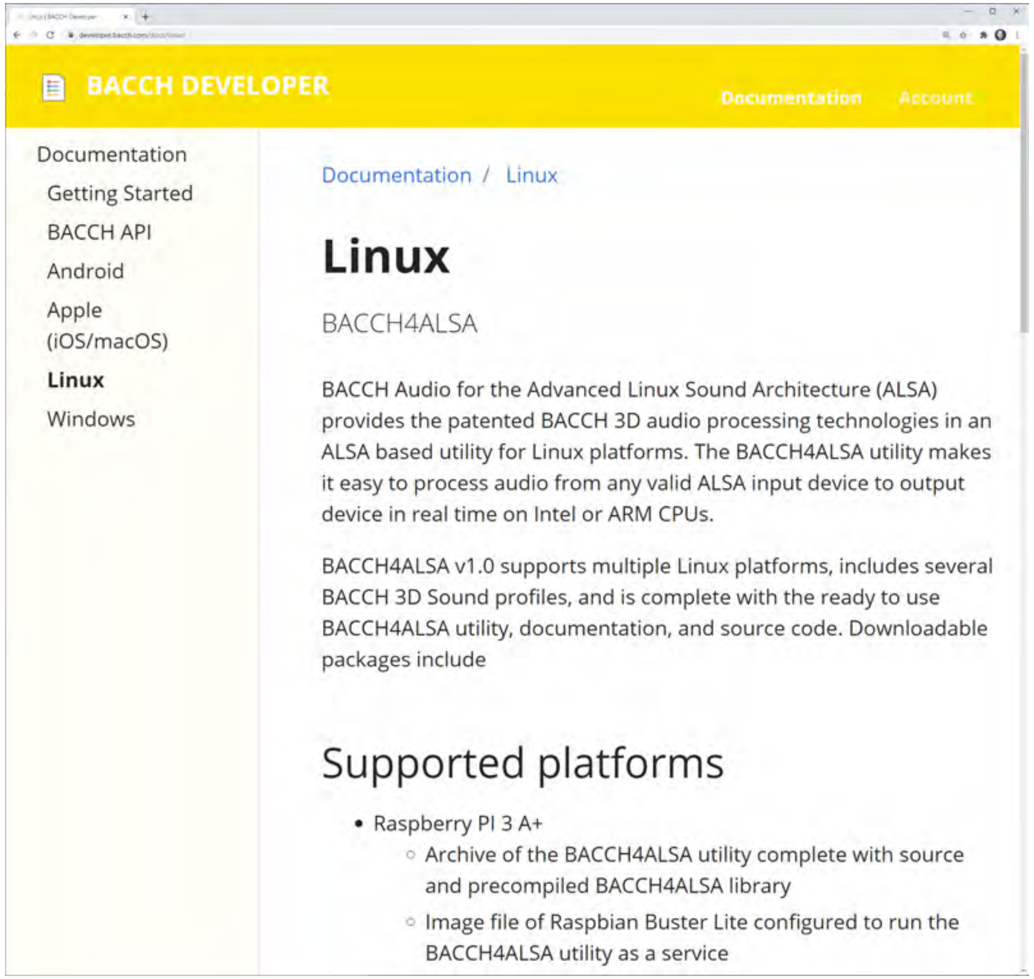
Filter Support: BACCH-SP

Chipset Support:
ADAU 1466 for BACCH-SP with Mono Correction.
ADAU 14xx for automotive headrest applications.
The ADAU series is memory constrained and other chipsets in that series are supportable at shorter filter lengths.

IP No. 45

BACCH4ALSA (a.k.a. BACCH Linux SDK)

Source: BACCH Labs
Type: Software



An Implementation of the BACCH Core Library for Systems That Incorporate the Advanced Linux Sound Architecture (ALSA) Framework

BACCH4ALSA is also known as the BACCH Linux SDK.

- BACCH4ALSA is used for embedded computing application
- BACCH Linux SDK is a more familiar name for desktop applications

Filter Support: All

Platform Support:

- Raspberry PI 3 A+
- NanoPi Neo
- Ubuntu 14.04 LTS
- Ubuntu 18.04 LTS
- Debian 10.5

IP No. 46

BACCH4Hexagon

Source: BACCH Labs
Type: Software

An Implementation of the BACCH Core Library for the Hexagon DSP Used in Qualcomm Snapdragon SoCs

Platform support: Hexagon Audio DSP v6 and later

Filter Support: BACCH-SP, BACCH-HP

BACCH Labs is a Qualcomm Advantage Network registered Independent Software Vendor (ISV).

BACCH4Hexagon Product Brief

5 Specifications

BACCH-SP. Loudspeaker Chain			
Mode	Latency (ms)	MIPS (raw instructions)	Memory (kB)
Lite	5.8	32.1	605
Low_Latency	5.8	141.9	1226
Standard	23.2	183.4	2148
High_Resolution	30.2	203.5	2212

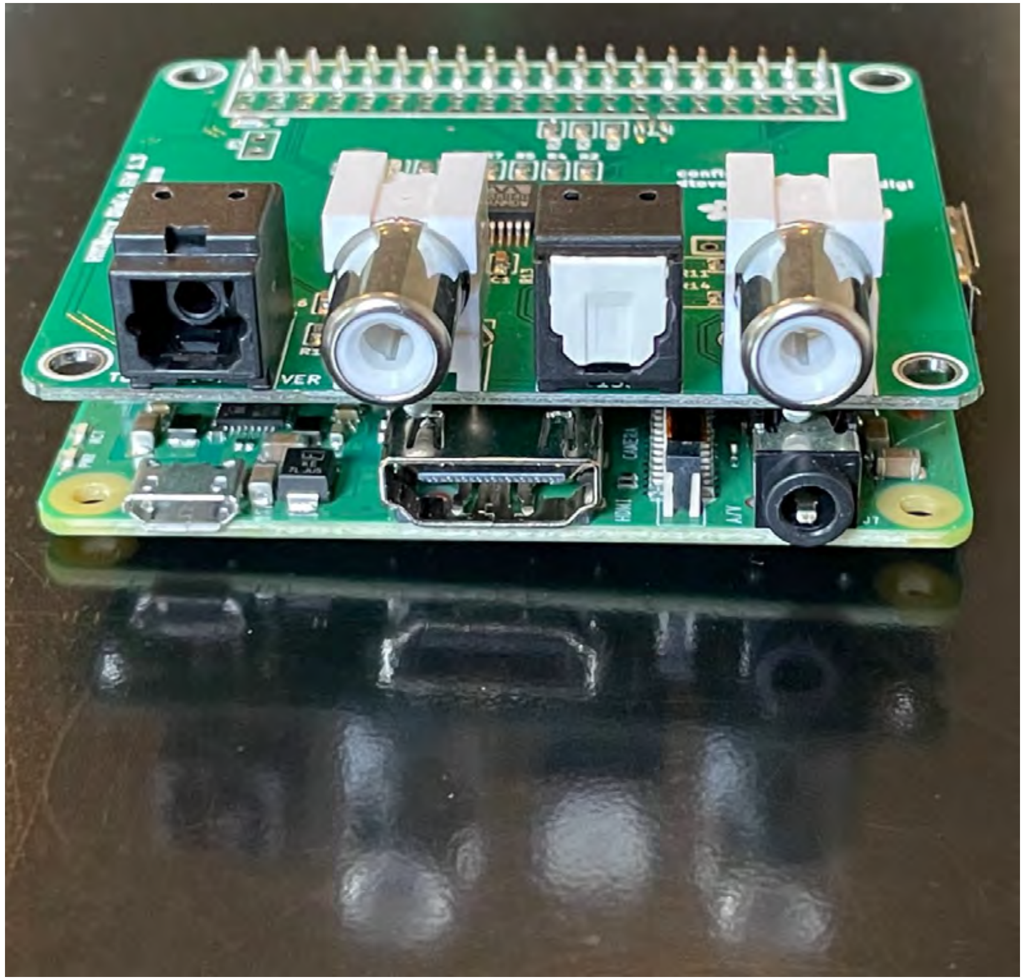
BACCH-HP. Headphone Chain			
Mode	Latency (ms)	MIPS (raw instructions)	Memory (kB)
Lite	2	172.7	2356
Low_Latency	7.8	302.5	2977
Standard	25.2	345.8	3892
High_Resolution	32.2	379.5	4497

BACCH in Bypass. Baseline to bypass with BACCH loaded but disabled			
Mode	Latency (ms)	MIPS (raw instructions)	Memory (kB)
Bypass	0	1.6	same as mode being bypassed

IP No. 47

BACCH Raspberry Pi Demo with HiFiBerry

Source: BACCH Labs
Type: Software



An Implementation of the BACCH Core Library and Supporting Application for the Raspberry Pi Along with HiFiBerry Sound Interface Board

Filters Support: All

Available as a software download, an SD card image, or a complete hardware package ready to in-line between TV and soundbar.

The Raspberry Pi Demo provides a fast method of adding BACCH Filtering as an in-line "Dongle" for fast prototyping and demo of any audio equipment.

Shown here with HIFIBERRY DIGI+ I/O board's SPDIF/Toslink connections, also easily supports for in-line analog audio filtering.

Shown here with the Raspberry Pi 3 A+, also supports the much smaller NanoPi Neo that can be concealed inside almost any device.

IP No.
48

BACCH Beagleboard Demo

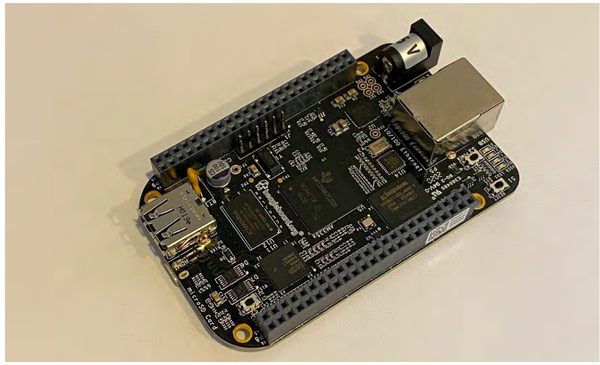
Source: BACCH Labs
Type: Software

An Implementation of the BACCH Core Library and Supporting Application for the Beagleboard AI and Beagleboard Black

Filters Support: All

Available as a software download, an SD card image, or a complete hardware package ready to add to your product.

All the features of the Raspberry Pi demos but on the Beagleboard. The Raspberry Pi (with Broadcom chip) and Beagleboard (Texas Instruments processor) are competitors. Both are commonly found already incorporated into audio products. Refreshing these hardware products with a software upgrade to add BACCH results in Fast-Time-To-Market for your next Product Refresh.



IP No.
49

BACCH SDK for Android

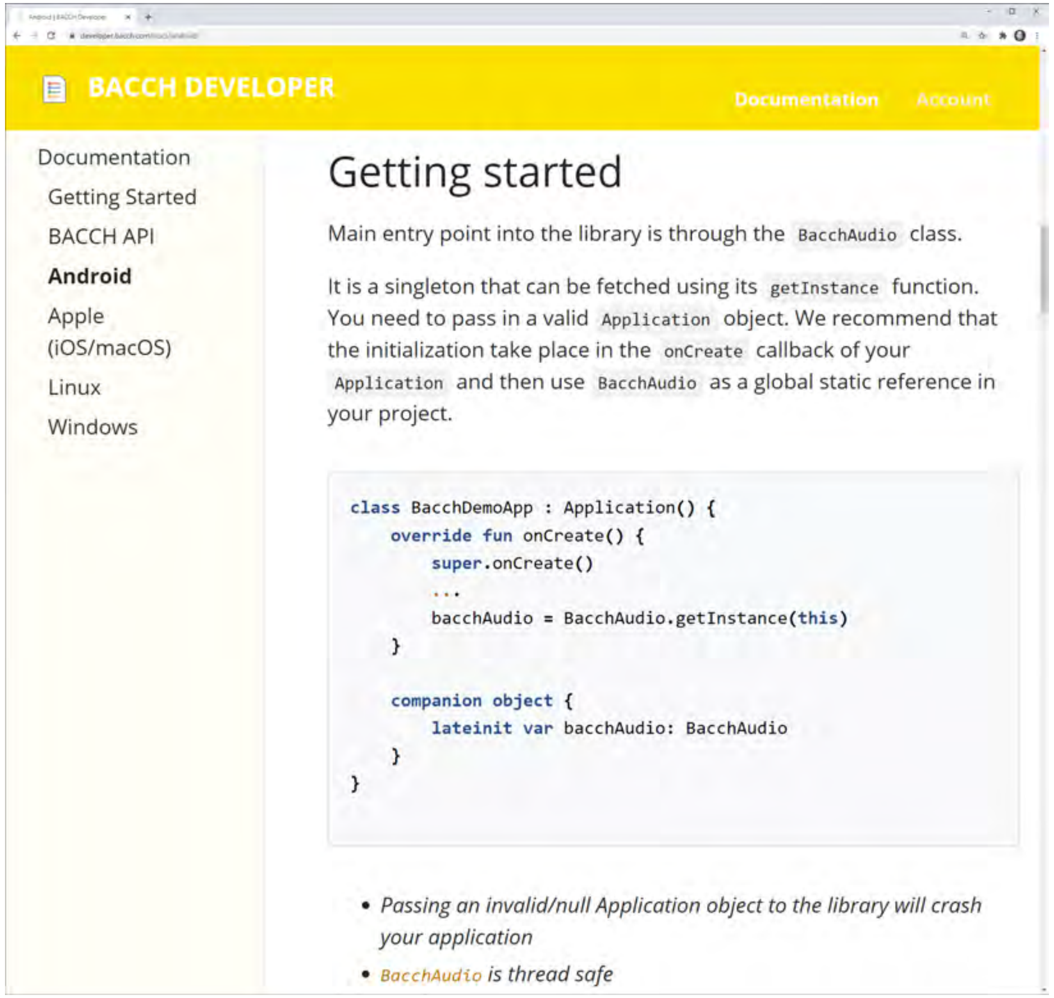
Source: BACCH Labs
Type: Software

An Implementation of the BACCH Core Library and Supporting Applications for Android

Filters Support: All

The BACCH Audio Android Library wraps the natively written BACCH Core Library in order to provide Android developers with an easy way to integrate our 3D Audio processing engine into their application. It features a friendly API which can be leveraged to communicate with and configure the BACCH Audio engine.

The BACCH Audio Android Library compiles with SDK version 29 (Android 10) and requires a minimum SDK version of 26 (Android 8).



IP No. 50

BACCH SDK for Apple

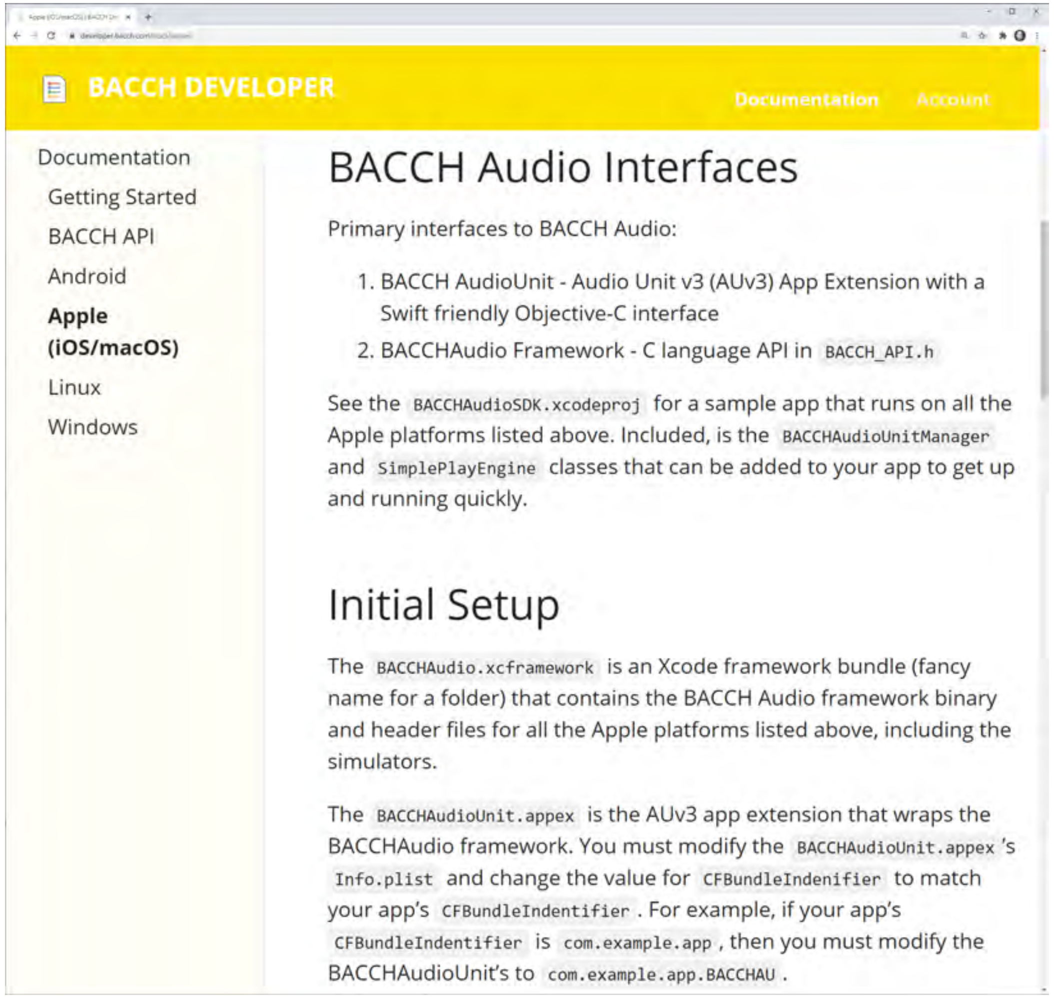
Source: BACCH Labs
Type: Software

An Implementation of the BACCH Core Library and Supporting Application for iOS and MacOS/X

Filters Support: All

This SDK contains the BACCHAudio framework with a C API, and the BACCH Audio Unit (AUv3) with a Swift-friendly Objective-C API, for seamless integration with your apps using AVFoundation or Core Audio.

Supported Apple Platforms
- macOS 10.13+
- iOS 12.0+ for Devices and simulators
- tvOS 12.0+ for Devices and simulators
- Mac Catalyst - UIKit on macOS



IP No.
51

BACCH SDK for Windows

Source: BACCH Labs
Type: Software

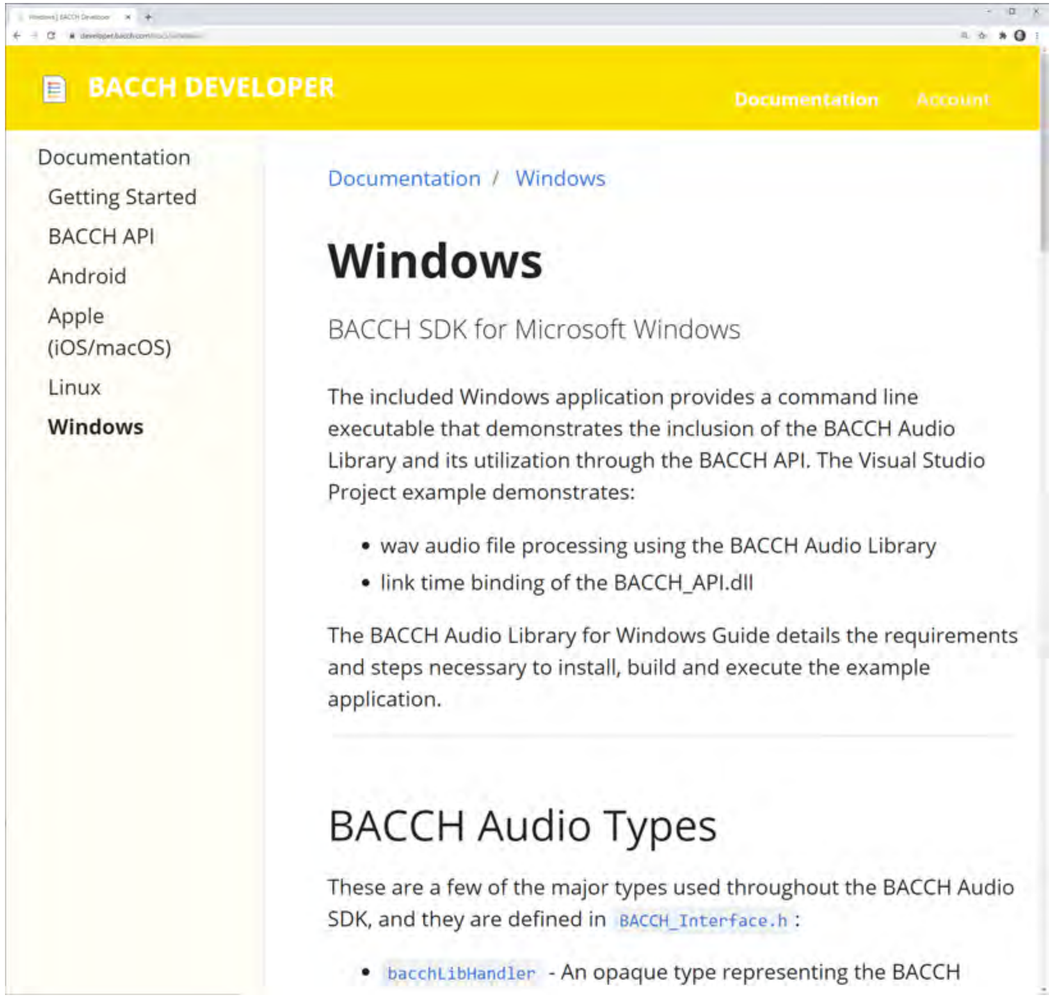
An Implementation of the BACCH Core Library and Supporting Applications for Windows

Filters Support: All

The included Windows application provides a command line executable that demonstrates the inclusion of the BACCH Audio Library and its utilization through the BACCH API.

The Visual Studio Project example demonstrates:
- wav audio file processing using the BACCH Audio Library
- link time binding of the BACCH_API.dll

The BACCH SDK for Windows is designed to build the Windows Audio Processing Objects (APOs) used to ship and receive Windows Certification on an audio effect in a specific OEM PC.



IP No.
52

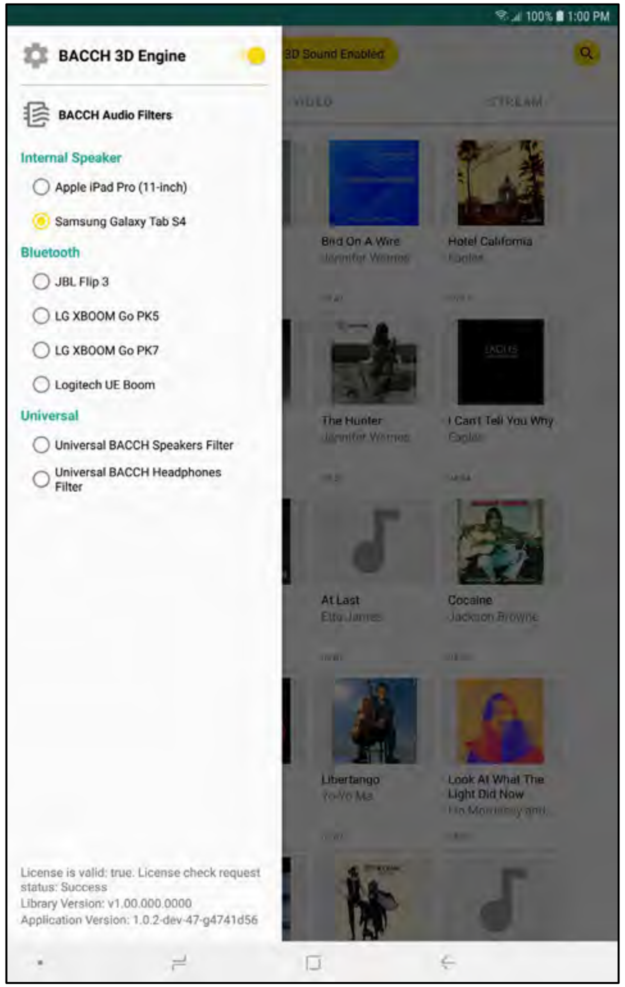
BACCH Android Demo App

Source: BACCH Labs
Type: Software

A Media Player That Demonstrates Using the BACCH Android SDK to Integrate BACCH into Your App

Demonstrated the use of the BACCH Android SDK with ExoPlayer, the open-source video player from Google used for the YouTube app.

The app itself is also available as a source code example for easy copy-paste-license enablement of BACCH in your app.



IP No. 53

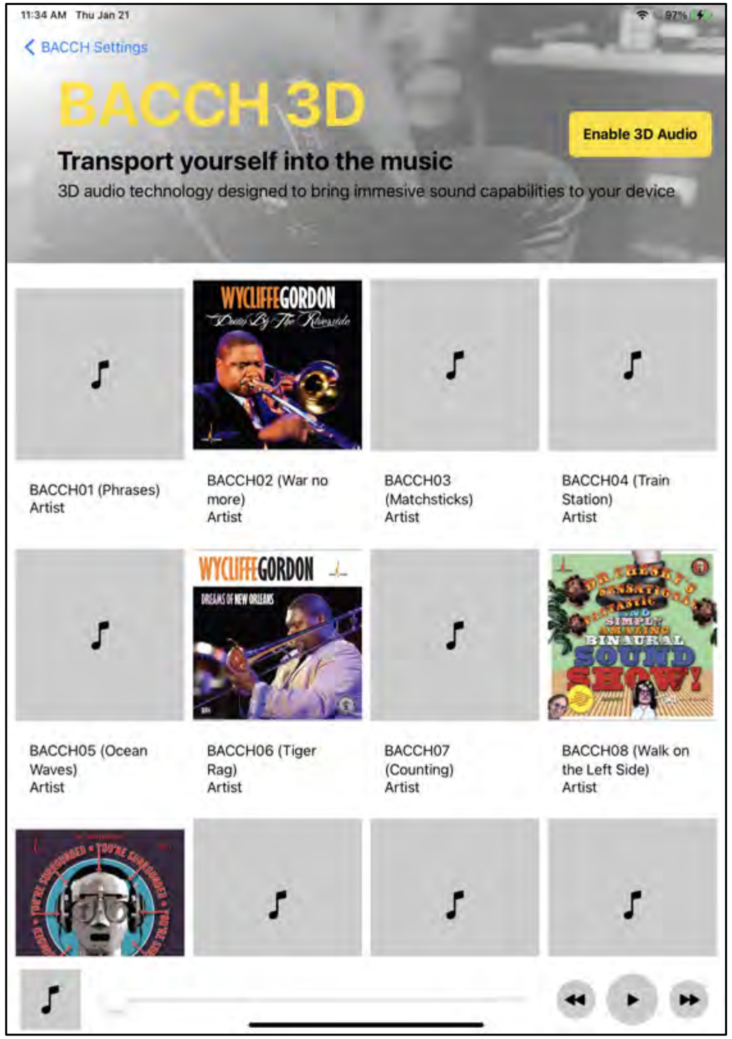
BACCH Apple Demo App

Source: BACCH Labs
Type: Software

A Media Player That Demonstrates Using the BACCH Apple SDK to Integrate BACCH into Your App

Demonstrates the use of BACCH's AudioUnit (AUv3) processing extension for Apple platforms.

The app itself is also available as a source code example for easy copy-paste-license enablement of BACCH in your app.



IP No. 54

BACCH IMU (Inertial Measurement Unit) Demo

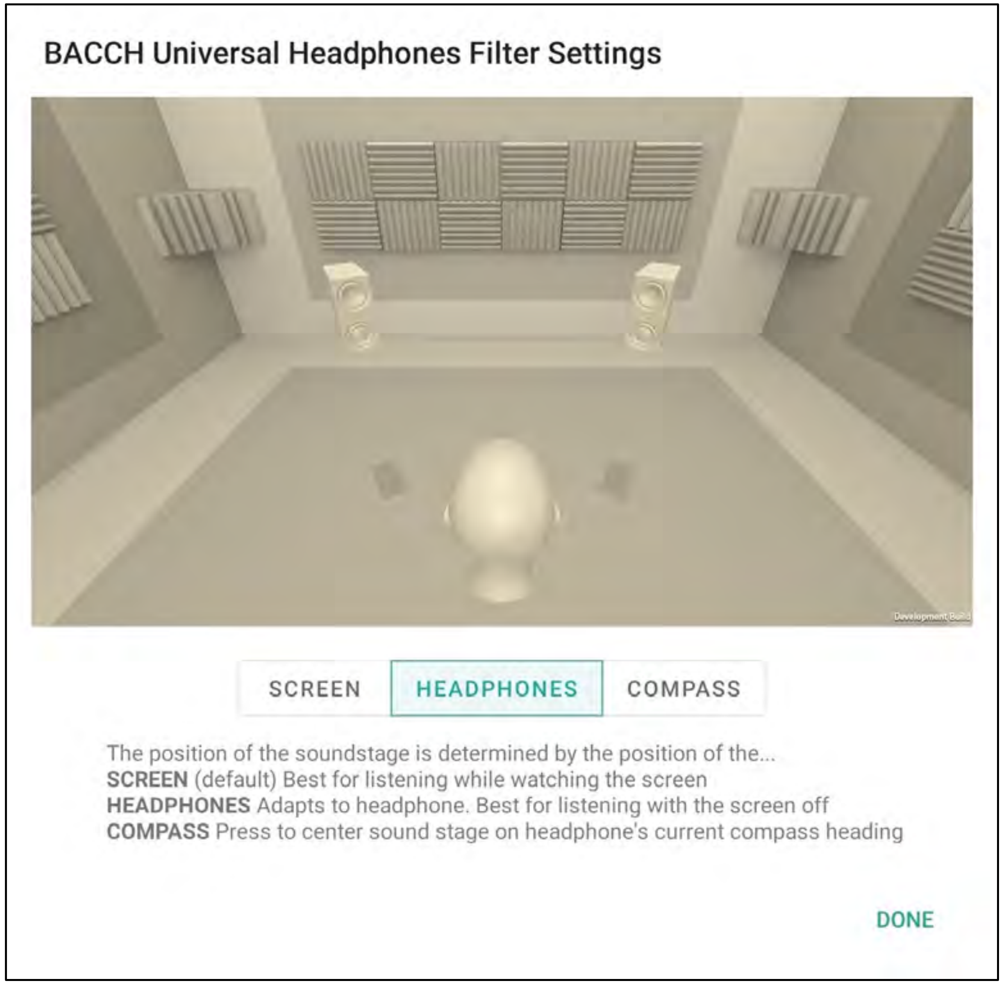
Source: BACCH Labs
Type: Software

A Software Module That Allows the Demo Apps to Showcase the Capabilities of BACCH-HP with Head Tracking

- Uses the MetaMotionR matchbook size IMU from MbientLab
- Clip the IMU onto any headphone to experience how your headphone can sound with BACCH and a Head Tracking IMU
- MetaMotionR uses the BMI160 IMU IC available from Bosch
- Available for Android and Apple Demo Apps

Showcases the BACCH-HP-HT Modes

- Screen. Centers the soundstage by comparing the heading of the IMU to the heading of the mobile device with the screen. Recommended when the screen is on any playing media.
- Headphones. Adapts to the low-pass filtered heading of the headphones. Works with the screen off. Also works completely agnostic of the media source and media device.
- Compass. The user can optionally orient the sound stage to a compass heading with the touch of a button.



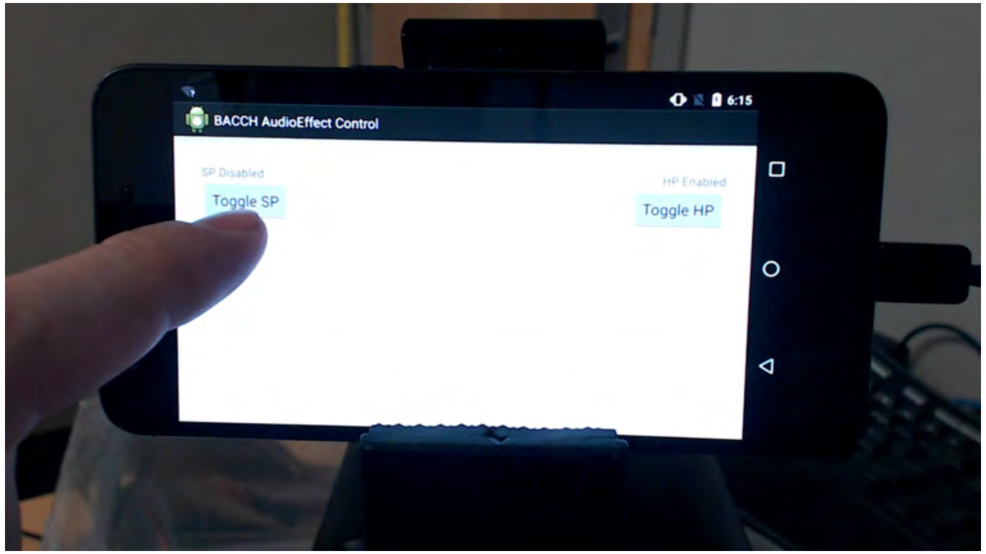
IP No.
55

BACCH AOSP Build

Source: BACCH Labs
Type: Software

Applies BACCH Sound to All of the Audio from a Smartphone

The Android Demo App only applies BACCH technology to the sound for that app. The Android Open Source Project (AOSP) Build enabled smartphone makers to apply BACCH sound to all of the audio from the device.



Features:

- BACCH incorporates an Android Audio Effect that is applied to all of the sound from the device.
- Runs the BACCH Core Library from the operating system (on a "generic" ARM/Neon processor) or from a dedicated Audio DSP, including the Hexagon Audio DSP in the Snapdragon SoC.
- The sample Control for BACCH shown is incorporated into the custom Setup App and 3rd Party Launchers used by Smartphone OEM's to "Turn BACCH on and off like WiFi" from Setup.
- Can be incorporated into any Smartphone or Qualcomm Reference Design. We showcase AOSP integration on the Nexus 6P because it has great stereo speakers.

IP No.
56

BACCH Surround Sound Virtualization

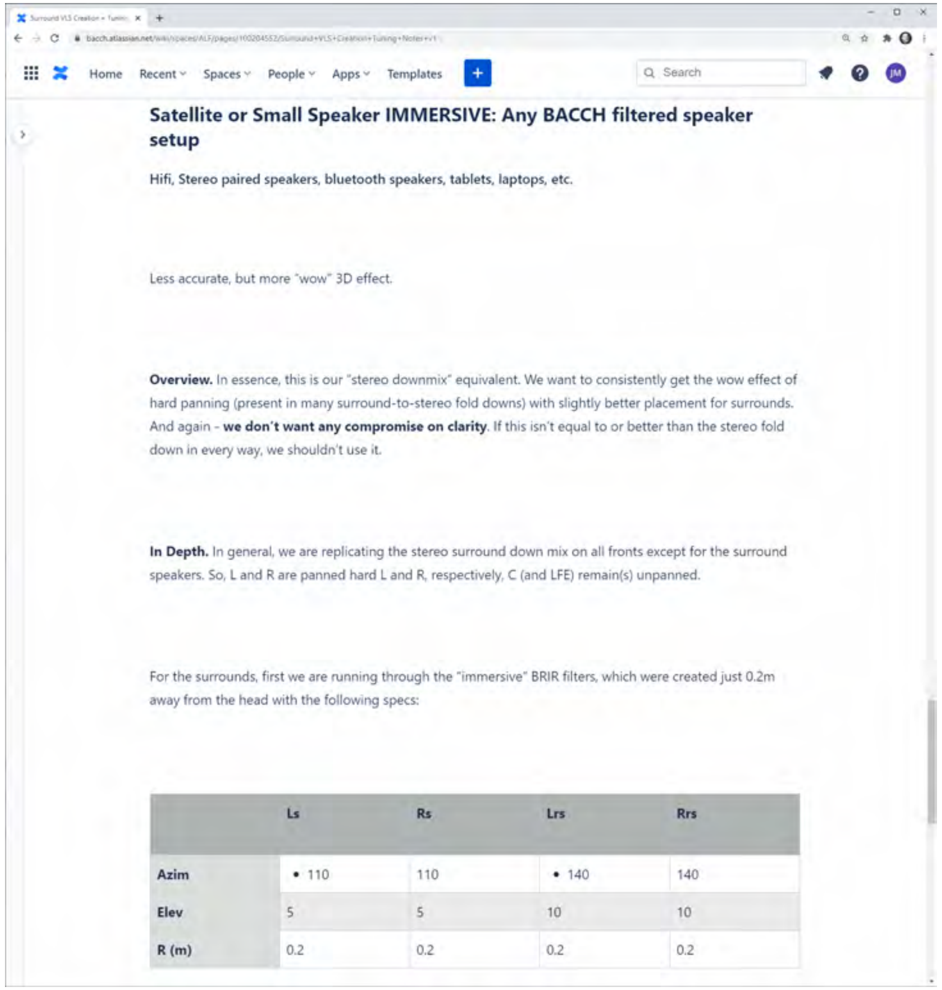
Source: BACCH Labs
Type: Software

Applies BACCH Sound within a Media Player App

The Android Demo Apps render the most impressive sound stage when applying BACCH 3D sound technology to stereo or binaural content. The Surround Sound Virtualization module converts Surround Sound to Binaural+ content that can then be rendered with BACCH-SP.

Features:

- Enabled playback of Virtual Surround Sound on two loudspeakers.
- Features presets for multiple use cases, such as large and small speaker and sound system sizes.
- Surround Sound Virtualization can be applied in the cloud to save streaming services on bandwidth – surround sound can be delivered in the lower bandwidth Binaural+ format.
- BACCH-HP's unique ability to hold a binaural sound stage still while rotating your head means that virtualization can be applied in the cloud, thus reducing lag and power consumption for the client device.



Satellite or Small Speaker IMMERSIVE: Any BACCH filtered speaker setup

Hifi, Stereo paired speakers, bluetooth speakers, tablets, laptops, etc.

Less accurate, but more "wow" 3D effect.

Overview. In essence, this is our "stereo downmix" equivalent. We want to consistently get the wow effect of hard panning (present in many surround-to-stereo fold downs) with slightly better placement for surrounds. And again - **we don't want any compromise on clarity**. If this isn't equal to or better than the stereo fold down in every way, we shouldn't use it.

In Depth. In general, we are replicating the stereo surround down mix on all fronts except for the surround speakers. So, L and R are panned hard L and R, respectively, C (and LFE) remain(s) unpanned.

For the surrounds, first we are running through the "immersive" BRIR filters, which were created just 0.2m away from the head with the following specs:

	Ls	Rs	Lrs	Rrs
Azim	• 110	110	• 140	140
Elev	5	5	10	10
R (m)	0.2	0.2	0.2	0.2

IP No.
57

BACCH Unity Plug-Ins

Source: BACCH Labs
Type: Software

A Set of Three Different Plug-Ins for the Unity Game Engine

BACCH Spatializer Plug-In

- Attached to each game object to render the sound from that object in Binaural+ with BACCH-3DM 3D Mixer technology.

BACCH Effect Plug-In

- Applied the appropriate BACCH processing and filter to all of the audio from the game after the sounds from all of the objects have been mixed into one game audio stream.
- Supports BACCH-SP and BACCH-HP filters

BACCH for Surround Sound

- Implements the BACCH for Surround Sound Systems patent, mixing objects between surround sound pairs and applying a filter to each pair.

IP No.
58

BACCH-MCX
(Multi-Channel Extraction)

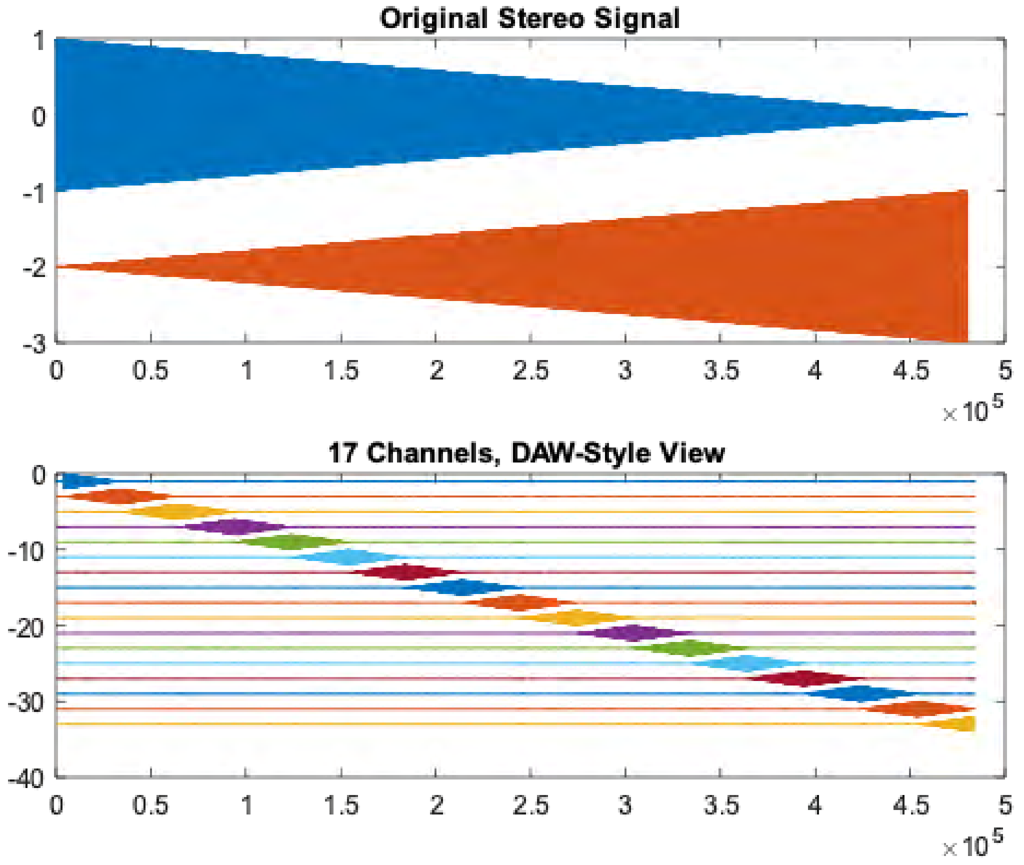
Source: BACCH Labs
Type: Software

BACCH-MCX (Multiple Channel Extraction) Software Uses a Cascade of BACCH Center Channel Extraction Processes to Create a Large Number of Channels

BACCH Center Channel Extraction converts L/R channels into L0/C0/R0 channels. It is a 2 channel to 3 channel upconverter.

L0/C0 can then be cascaded to extract an upconverted channel between them, and so forth. The process is used to upconvert 2 channel audio to 3, 5, 9, and 17 channels.

Creatives can then arrange these channels in space with the BACCH-3DM to create unique effect exceeding the novelty of the 8D content currently trending on YouTube.



IP No.
59

Secure Network Database Access

Source: BACCH Labs
Type: Software

Code for Secure Network Database Access and Server Synchronization

This is "glue" used to make sure our Network Database Access is done correctly and securely.

This code is included in the IP List because it is a snapshot of source code for commercial software that BACCH Labs has both purchased from another company and sold to other companies. This "glue" logic is getting "passed around" because it is superior to the equivalent open-source offering.

- Database Access and Manipulation
  - INCLUDES Server-side code that is used to access, add, modify, delete, and maintain records stored in a database in a pseudo-standard or standard way that we would like adopted by other tools in the industry upon which we would like to maintain compatibility with future versions.
- Network infrastructure code
  - INCLUDES code that makes the transmission of information possible for any combination of client, server, and web infrastructure, including University port policies.
- RESTful interface structure code
  - INCLUDES code that makes the server act slightly differently for each browser so that features work the same way across different client web browsers.
- Server to Server synchronization code
  - INCLUDES code required to keep multi-zoned servers synchronized with each other for the purpose of high availability in a pseudo-standard or standard way that we would like adopted by other tools in the industry upon which we would like to maintain compatibility with future versions.

IP No.
60

BACCH-BM Pro
(in-ear Binaural Microphone)

Source: Theoretica
Type: Hardware

State-of-the-Art In-Ear Binaural Microphone with Proprietary Capsules and Circuitry with Individual Free-Field Equalization for an Ultra-Flat Response Up to 30 kHz and Record SNR for Its Size

The BACCH-BM Pro uses an ASIC amplifier, which provides high ESD and RFI tolerance as well as consistent biasing characteristics compared to single FET amplifiers, the BACCH-BM Pro has the highest signal-to-noise ratio, sensitivity, and frequency extension of any microphone its size.

A high-precision analog signal conditioning circuit is embedded in an xlr5 connector and each pair is individually calibrated using the BACCH-BMC algorithm (IP#22). Proprietary electret condenser, polar pattern: Omnidirectional; size: 5.6 mm diameter, 11.7 mm length; phantom power +48 V; Frequency range (+/- 1 dB, w/ EQ) 20 Hz - 30,000 Hz; sensitivity -35 dB re. 1 V/Pa (±3 dB); 17.8 mV/Pa equivalent noise level 27 dB(A) s/n ratio re. 1 kHz @ 1 Pa (94 dB SPL) 67 dB.

The BACCH-BMC Pro is used around the world by audiophiles, pro audio professionals, university researchers and companies including NYU, U of Rochester, American Univ., Chamber Music Society at Lincoln Center, and Chesky Records, where it as used to record the last 4 albums in the Binaural+ series, including a Stereophile award winning album.

IP No. 61

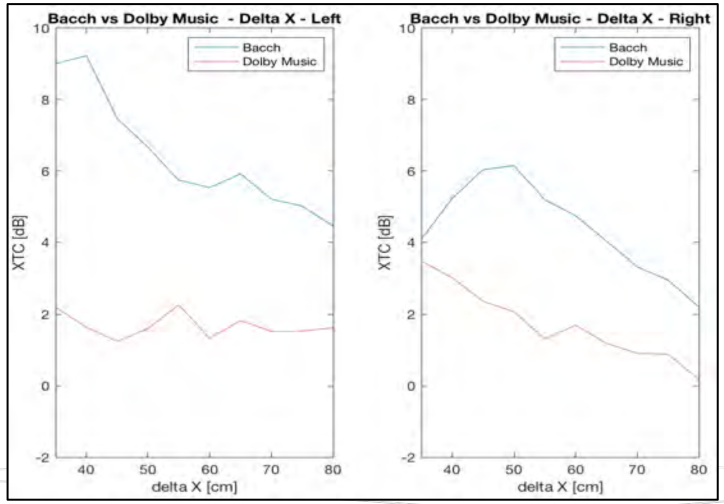
Sweet Spot Automated Test System

Source: Bacch Labs
Type: Hardware

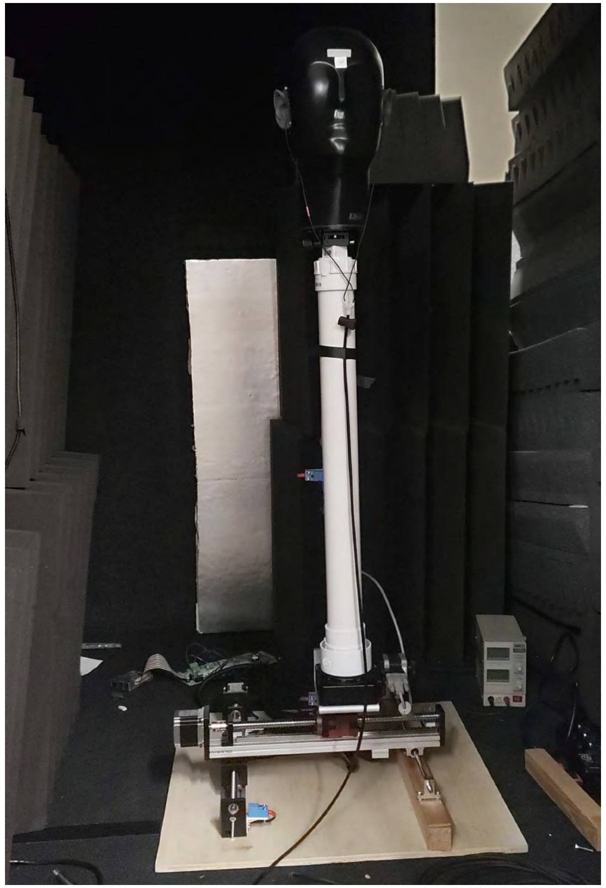
A Set of Servo-Controlled Positioning Systems and Rotating Platters That Allow Dummy Heads and Speakers to Be Rotated and Translated Automatically

The most popular use for this test hardware is to step through a series of angles or distances and measure the level of crosstalk cancellation at each location.

Because BACCH has the highest levels of crosstalk cancellation in the industry, we are often asked to generate test data comparing the volume and quality of a BACCH sweet spot to other technologies. This hardware enables those tests to be automated and repeatable.



The Automated Servo Hardware and Software was used to measure the XTC performance of a BACCH-SP filter compared to a Dolby Atmos Music Mode filter on the same handset as a function of distance from the listener to the handset. The results show that BACCH has higher level of XTC at both ears throughout the entire measurement range.



IP No. 62

BACCH Trademark

Source: Princeton University
Type: Trademark

Trademark on the Word BACCH

Application serial no. 85977292.

REGISTRATION DATE: 07/30/2013

MARK: BACCH(Standard Characters)

The owner, The Trustees of Princeton University, non-profit corporation legally organized under the laws of New Jersey, having an address of
87 Prospect Avenue
Princeton, New Jersey 08544
United States
609-454-3500
cdrachtman@meagheremanuel.com (authorized)
is filing a Declaration of Use and/or Excusable Nonuse of Mark in Commerce under Section 8.

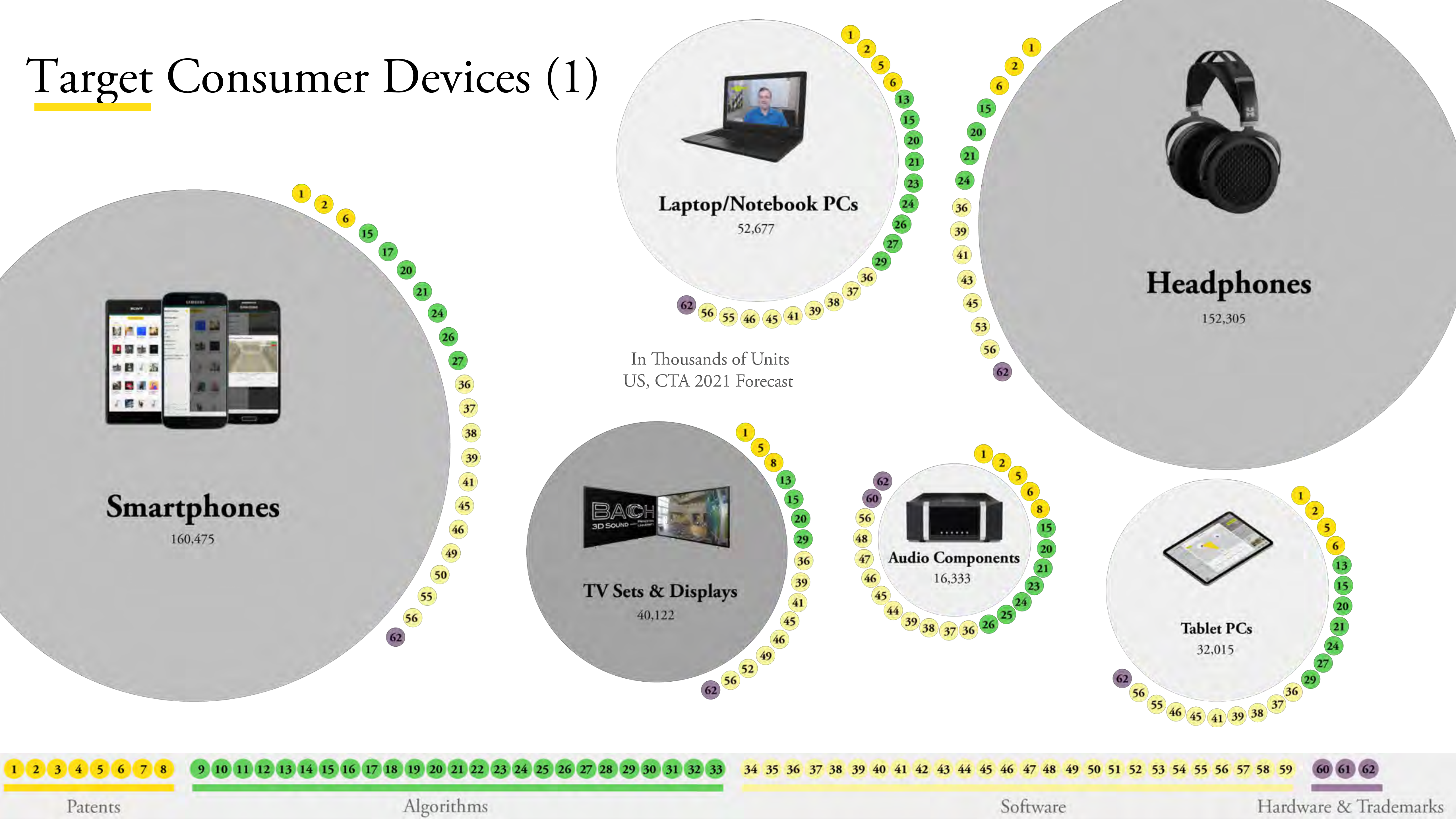
For International Class 009, the mark is in use in commerce on or in connection with **all** goods/services, or to indicate membership in the collective membership organization, listed in the existing registration for this specific class: Stereo equipment, namely, personal stereos, audio speakers, digital audio processors, namely, signal separating and converting circuitry or software for audio signals, all of the foregoing for use in providing three dimensional audio ; or, the owner is making the listed excusable nonuse claim.

BACCH
3D SOUND Invented @ PRINCETON UNIVERSITY

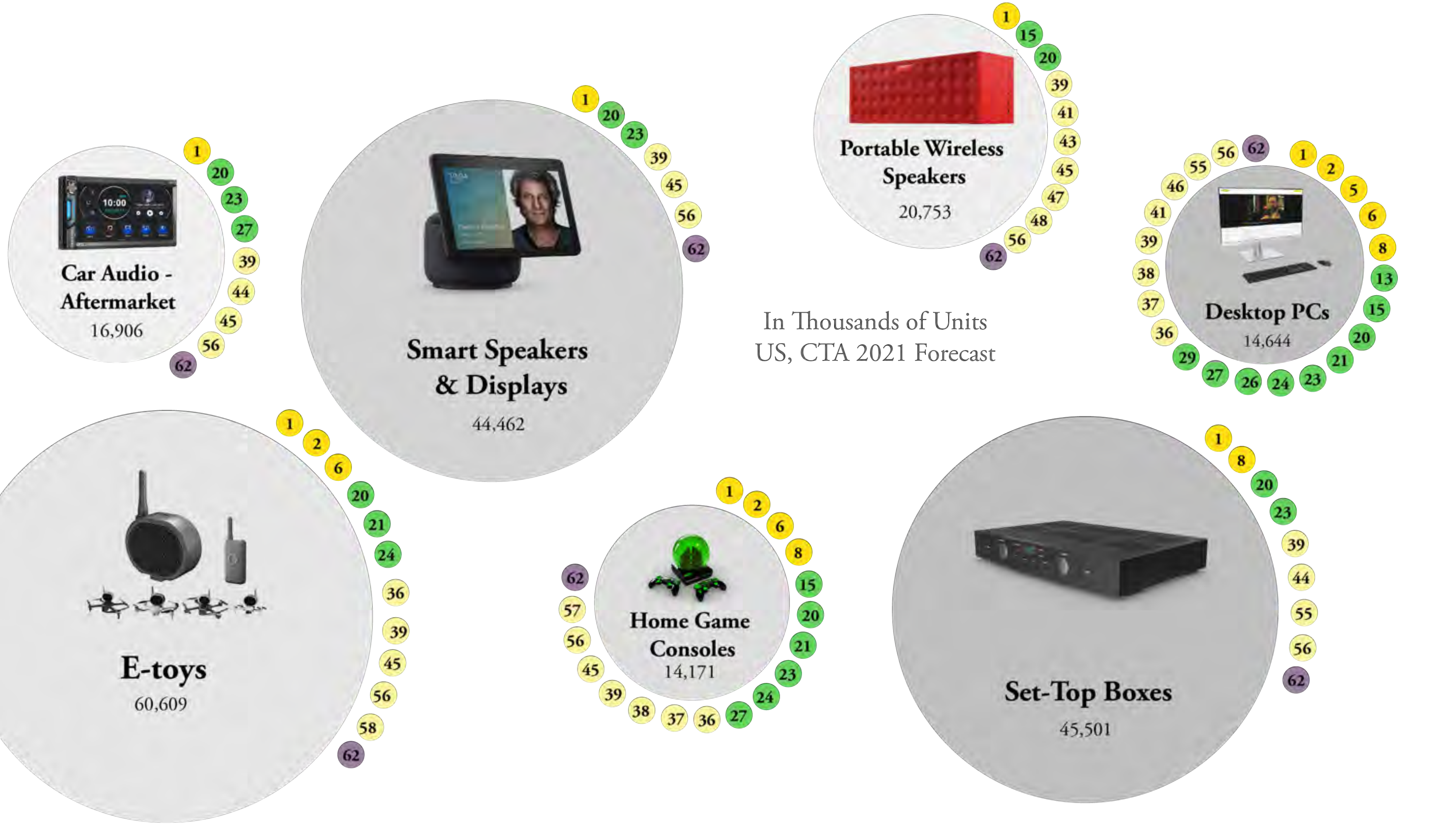
IP Sources

IP Source Type	Description
Princeton	IP assigned to Princeton and licensed exclusively to BACCH Labs.
BACCH Labs	IP invented by and assigned to BACCH Labs.
BACCH Labs / Joint	IP jointly owned by BACCH Labs, its source supplier, and its customer(s).
Theoretica	IP invented by Theoretica and licensed exclusively to BACCH Labs. As of June 24, 2020, Theoretica's IP is licensed exclusively by BACCH Labs.

Target Consumer Devices (1)



Target Consumer Devices (2)



Aftermarket PC Monitors 7,300
1 3 5 13 15 20 29 39 45 56 62

Portable Media Players 4,127
1 2 6 20 21 24 36 39 41 45 56 62

Disc Players 3,918
1 2 8 20 21 23 24 26 37 38 39 41 45 49 56 62

Portable Game Consoles 3,169
1 2 5 6 15 20 21 24 27 29 45 56 57 62

OTC Hearing Aids 3,042
2 6 15 20 21 24 27 39 45 62

Portable Media Player Speakers Docks 2,425
1 20 39 45 56 62

VR Headset/Eyewear 2,268
2 15 16 17 20 21 24 26 27 37 38 39 40 41 45 56 57 62

AR Headset/Eyewear 553
2 15 16 17 20 21 24 26 27 37 38 39 40 41 45 56 57 62

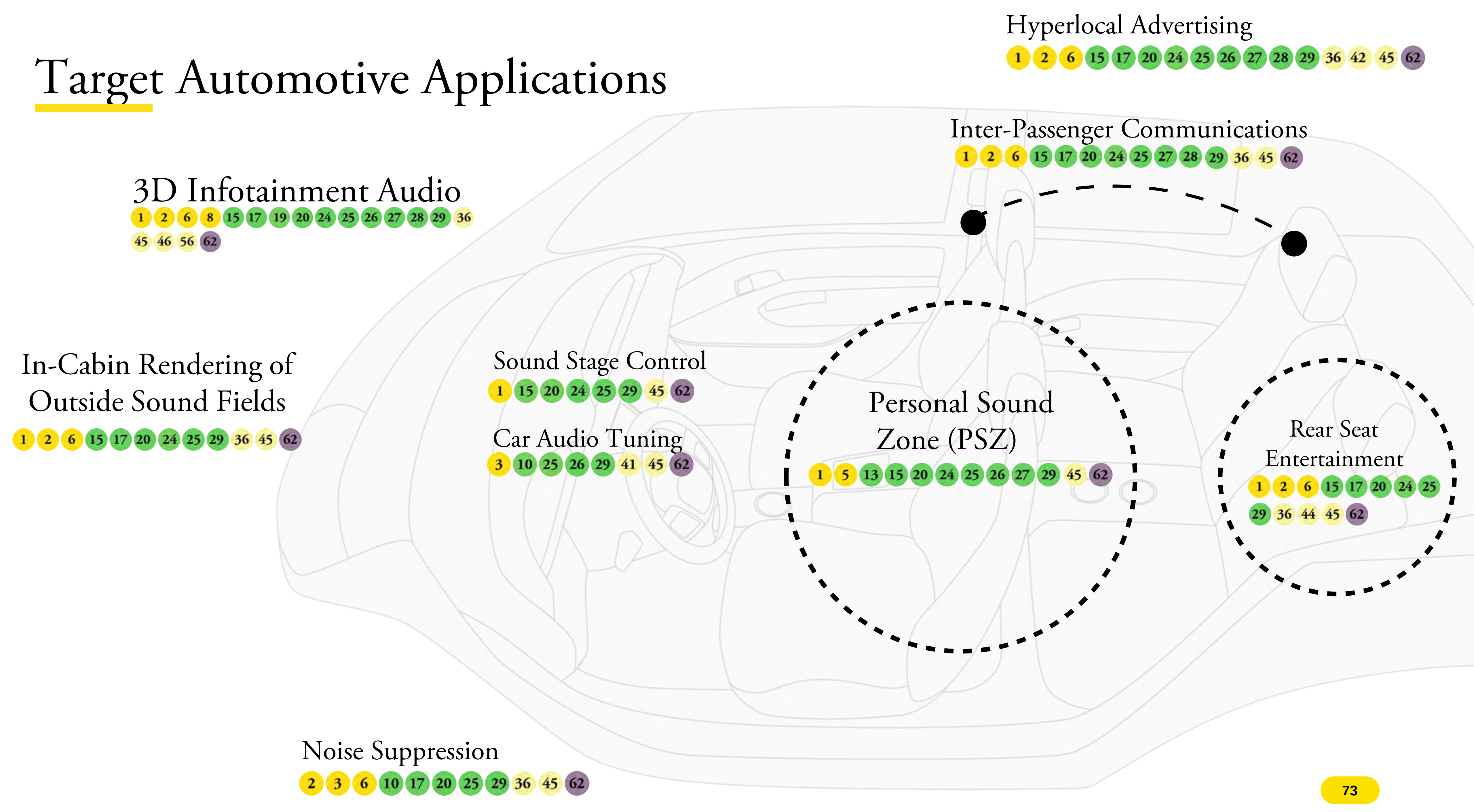
Compact Audio Systems 454
1 2 8 20 21 22 23 24 37 38 39 44 45 46 47 48 56 62

Home Theater-in-a-Box 269
1 2 8 20 21 23 24 26 39 45 46 47 48 56 62

Target Consumer Services

	**Video Conferencing** **Global, Desktop**	**10 Million** Global Users	1 2 16 17 19 20 21 23 24 36 37 38 39 40 41 42 49 50 51 52 53 57 59 62
	**Live Video Streaming** **North America**	**21 Million** North American Users	1 2 16 17 19 20 21 23 24 37 38 39 40 41 42 49 50 51 52 53 56 62
	**Subscription Music Streaming Services** **United States**	**81 Million** United States Users	1 2 16 17 19 20 21 23 24 37 38 39 40 41 42 49 50 51 52 53 56 62
	**Subscription Video Streaming Services** **United States**	**287 Million** United States Users	1 2 16 17 19 20 21 23 24 37 38 39 40 41 42 49 50 51 52 53 56 62
	**Video Editing Tools** **Conservative Forecast**	**7 Million** Users	1 2 3 4 6 7 8 9 13 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 35 36 37 38 39 56 58 60 62

Target Automotive Applications



Target High-End/Pro Audio Applications

3D Audio Processors

1 2 6 8 16 17 19 20 23 25 29 33 36 37 38 45 56 62

DACs

1 2 6 17 20 36 45 62

Headphones

2 6 17 20 26 36 39 40 45 47 54 62

DSP-Enabled Speakers

1 8 20 21 22 23 39 40 45 47 48 56 60 62

Binaural Recording & Production

15 18 21 22 24 26 27 28 29 34 35 39 40 45 60 62

3D Audio Mixing & Mastering

15 18 19 23 24 26 27 28 29 33 34 35 39 40 45 62

Sound Field Navigation

4 15 24 26 27 28 29 34 35 39 40 45 62

Beam Formation and Directivity Controls

15 24 26 29 30 31 32 34 35 39 40 45 62

Contact us today.

james@bacch.com