AMBEO

3D AUDIO TECHNOLOGY BY SENNHEISER

Approaching Static Binaural Mixing with AMBEO Orbit

If you experience any bugs with AMBEO Orbit or would like to give feedback, please reach out to us at ambeo-info@sennheiser.com

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Definition of Static Binaural Audio

Static binaural is a favorable and economical method for implementing an immersive 3D audio experience, requiring little to no additional equipment on the part of the audio engineer or the end listener.

Static binaural audio describes a stereo audio signal that implies Head Related Transfer Functions (HRTFs), resulting in an externalized, immersive spatial listening experience that is perceived in three dimensions. The HRTFs replicate the natural acoustic information rendered by a listener's anatomy. A listener's ears rely on three perceptual properties of an observed sound source to determine its spatial location: interaural time difference (ITD), interaural intensity difference (IID), and the resonances and filtering effects of the listener's ear pinna, head, and body.

Because these three spatial properties are applied during the capture and mixing stages of static binaural audio production, static binaural content does not require any decoding on the part of the engineer or end listener, and can be experienced with any headphone.

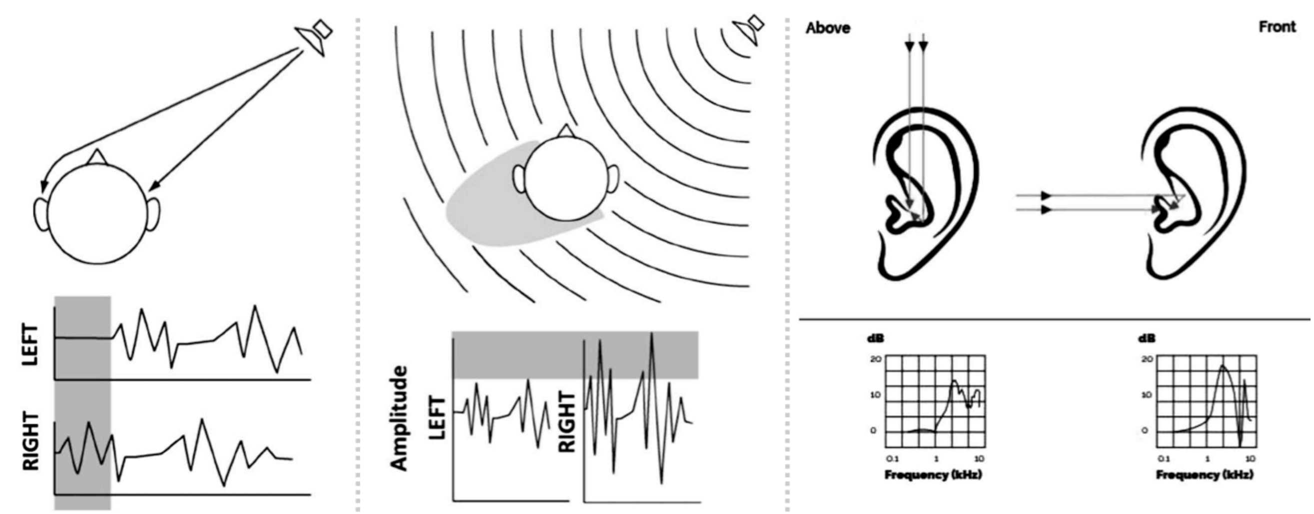


Figure 1: ITD, IID[1], and spectral filtering[2]

A static binaural mix presents the listener with a fixed soundfield – in other words, it does *not include headtracking*. This gives the mixing engineer an extremely high level of control over the experience, as the listener has no input into the system. This also allows the mixing engineer to approach 3D audio mixing with a very similar workflow to traditional stereo mixing applications, as we will see.

Hardware Equipment: Inputs

Virtually any audio signal can function as an input in a binaural mix. This includes:

Mono content, such as microphones, DI signals, audio samples, software instruments, and so on. These mono sources can be placed anywhere around the listener in three dimensions in a static binaural mix.

Multichannel content, such as stereo signals, 5.1 stems, 7.1 stems, and so on. When mixing a stereo signal, the two sources can be independently or relatively positioned for the desired width and spatial location. When mixing multichannel content, this approach also allows an engineer to create a surround-speaker mix over headphones by positioning each multichannel track at the virtual location of its corresponding speaker.

A “binaural stereo microphone” recording. The simplest method of capturing a performance in static binaural is by use of a binaural stereo microphone (BSM), or colloquially, a “dummy head microphone” such as the Neumann KU100. Constructed to replicate the anatomy of a human head, a BSM contains a microphone capsule in the canal of each artificial ear and performs HRTF filtering naturally by design. A BSM is excellent for capturing the complete audio scene of a performance, and particularly the reverberation and ambient acoustical environment of a recording location.

Hardware Equipment: Outputs

Closed-back headphones, while ideal for recording environments, are not ideal for a binaural mixing environment. Their closed construction can create internal resonances that jeopardize playback accuracy by reinforcing lower frequencies. Additionally, closed-back headphones can tend to slightly lessen the externalization of a binaural signal, drawing sources' perceived location closer to the listener than they may be represented in open-back headphones.

Open-backed headphones such as the Sennheiser HD 650, on the other hand, tend to exhibit a flatter frequency response and finer level of detail for making tuning judgments between tonal preservation and externalization of a binaural signal. Also, open-back headphones are typically less fatiguing and more comfortable to wear, which can be essential to ensure good judgment throughout long mixing sessions over headphones. Remember to take regular breaks from headphone listening to let your ears breathe, and always mix at an appropriate volume.

Mixing binaural on speakers, while not necessarily "incorrect", is discouraged unless it is anticipated that the end-listener may experience the mix on either headphones *or* speakers. In this case, it is advised that the mixing engineer focus primarily on mixing over headphones, while occasionally monitoring on speakers to determine an optimal balance. Binaural mixes, depending on how they are mixed and the degree of their externalization, can sound great on speakers – however, the immersive 3D impact of the mix will be effectively rendered null and void.

Using the Neumann KU100

Figure 2: Neumann KU100 Binaural Stereo Microphone

The Neumann KU100, affectionately known as “Fritz”, is a binaural stereo microphone (“BSM”). It resembles the anatomy of a human head and has two high-quality Neumann microphone capsules built into the ear canals.

Power Supply and Controls: The KU 100 can be operated with typical 48V phantom powering, or from an external power supply unit, or from the built-in battery. At the bottom of the unit is a switch for the different power supply modes, as well as connectors for balanced and unbalanced output signals. A -10 dB switch inside the head attenuates the sensitivity. A second switch selects the cutoff frequency of the high-pass filter to be either linear, 40 Hz, or 150 Hz. It is recommended that you use typical external phantom power.

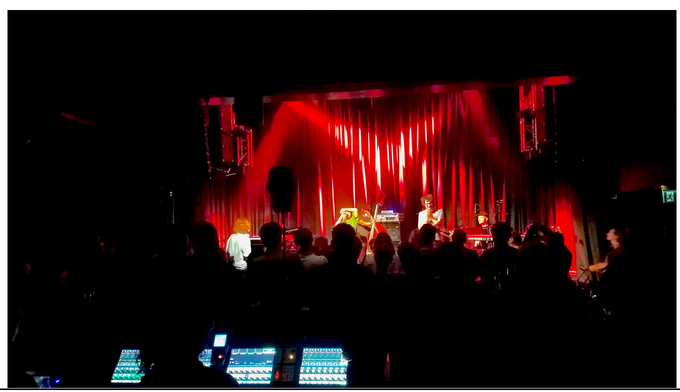
Connection: The bottom of the KU100 accepts a 5-pin XLR output cable, which can be split via the included adapter cable into two 3-pin XLR connectors – yellow is the left channel, red is the right channel. Phantom power must be applied to *both* of these 3-pin XLR connectors individually, and the flip switch at the bottom of the head must be set to “P48”.

Recording and Playback: The left and right channels from the KU100 should be panned 100% left and right, respectively.

See the operating manual for further information at:
https://www.neumann.com/?lang=en&id=current_microphones&cid=ku100_manuals

KU100 Microphone Placement

As the KU100 can only replicate the sonic experience at a particular location, choosing its placement position is a very important decision. Depending on the desired experience for the end listener and the nature of the performance, an engineer may choose to position the KU100 directly on stage with the performers surrounding it, in the front row of the audience, or further back in the recording location and above the audience, for example. The nature of both the performance and venue will dramatically impact the efficacy of certain placement positions. For example, positioning the KU100 directly on stage may produce the best results for an acoustic folk trio performance, but may produce unusable results for an electronic pop band. We have developed a set of guidelines for determining BSM placement position:



KU100 on stage or at front of stage:	**KU100 in or above the audience:**
- Mostly acoustic instruments	- Mostly electric instruments
- Good “stage” sound	- Poor “stage” sound
- Not much reliance on PA system	- Heavy reliance on PA system

For performances that do not rely heavily on loudspeaker amplification (PA), contain mostly acoustic instruments, and thus tend to have a better “stage sound”, placing the KU100 directly on stage or near the front of the stage can produce the most impressive and immersive results. On the other hand, for performances that rely more heavily on PA loudspeaker amplification, contain several electronic instruments, and thus have a better “venue sound”, placing the KU100 amid the audience, and facing the PA system, can produce the most appropriate and immersive results.

Psychoacoustics and “Dereverberation”

Additionally, in the context of a static binaural stream that includes video content, it is important when placing the KU100 that one takes into account the appearance of the video that the audio will accompany. A drastic difference between a performer’s position on-screen and their position in the static binaural audio scene may yield undesirable psychoacoustic effects, causing the audio to sound unnatural and less immersive for the end listener. It is important to note that psychoacoustics play an important role in binaural audio. When a listener’s visual perception matches their auditory perception, the brain is often able to apply *dereverberation* to what it hears. For example, imagine watching an orchestra in person from the back of a classical concert hall. Despite being positioned relatively far from the orchestra, one can still have a strong, punchy, and gripping listening experience. When lis- tening on headphones to the output of a KU100 placed in the exact same location, one would expect to have a similar experience. However, although the output is very similar to what one hears in reality, the dereverberation applied by one’s brain in-person does not apply to a binaural recording. Therefore, a binaural recording can often sound too distant from the intended sound source. These psychoacoustic effects are important to bear in mind when determining the placement of the KU100.

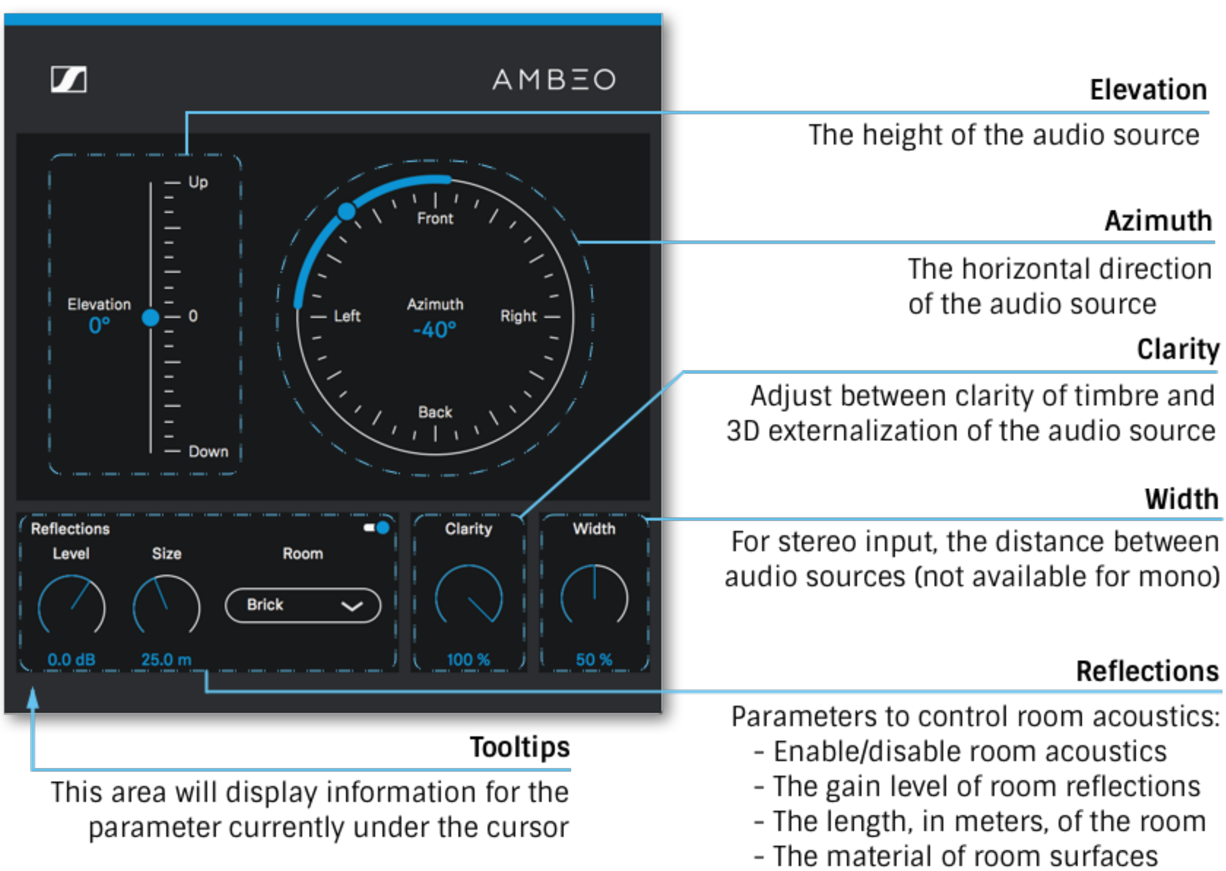
Figure 3: Neumann KU100 Placement on Stage

Combining the KU100 with Spot Microphones

Although with proper positional placement KU100 is the ideal tool for capturing the complete scene and acoustical environment of a musical performance, a KU100 recording alone is often not sufficient to produce a pleasing complete mix because of unavoidable practical limitations on its possibilities for placement position. These limiting factors include the number and arrangement of performers on stage, the location of their instruments, equipment, and stage monitors, the dynamic range of the instruments present and means by which they produce sound, the nature of the musical content, and/or the layout of the recording location and subsequent feasibility of placing the KU100 amid the audience if needed. Additionally, while a KU100 recording captures the entire performance and location extremely well, it alone does not provide the flexibility required by most modern recording workflows. For many performances, it can be impossible to achieve a balanced mix without control over each of the instruments individually. For this reason, it favorable to augment the KU100 recording with binaurally-rendered spot microphones, using AMBEO Orbit.

Using AMBEO Orbit

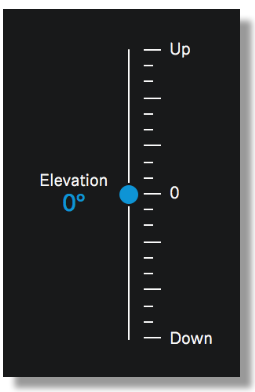
Excluding the KU100 signal, *all other signals* (spot microphones, recorded samples, software instruments, etc.) used in a DAW will contain no spatialized 3D acoustic information on their own. Therefore, in order to be "placed" in 3D acoustic space, these signals must be binaurally rendered. This processing is applied with the AMBEO Orbit plugin within your DAW. Orbit is a binaural panner that applies HRTF filtering to an audio signal to produce a virtual 3D spatialization. It can be initially thought of and approached as a normal pan-pot, except with the ability to place a signal in any location left, right, above, below, in front or behind – instead of only left or right. Orbit provides other additional functionality, however, and is organized like so:



AMBEO Orbit is a powerful and streamlined binaural panner that contains several unique features that are unavailable with any other plugin. It is available in all major formats, including VST, VST3, AU and AAX, and is supported on Windows and macOS. It is controlled with the following parameters:

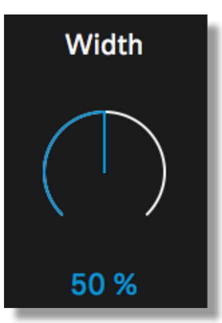
Azimuth

This controls the horizontal position of the source in degrees. 0º is directly ahead, 90º to your full right, -90º to your full left, and 180º directly behind you.



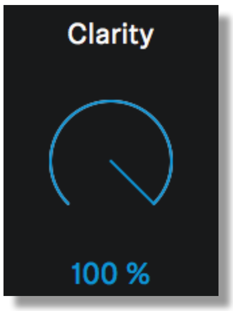
Elevation

This controls the vertical position of the source in degrees. 0º is at ear-level, 90º is directly above, and -90º is directly below.



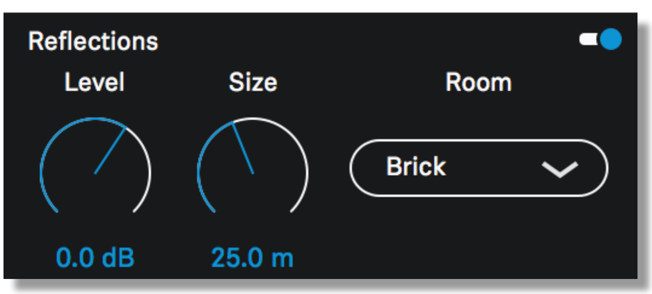
Width

When Orbit is given a stereo input, this controls the relative distance between the left and right channels as sources. 100% places them at a maximum distance apart, and 0% collapses them to mono. If Orbit is given a mono input, this control is disabled.



Clarity

Because HRTF filters must alter the frequency response of a signal to impart 3D spatial information, they ultimately color the sound of the original signal. Therefore, finding an optimal balance between the externalized 3D perception and the overall tonal preservation of a recording can be very important and useful. This parameter controls this balance, such that 0% is full 3D externalization of the source, and 100% is full "clarity" or original tonal balance. Clarity can be especially useful for musical instruments and the human voice.



Reflections

This section controls the acoustics of a surrounding virtual shoebox-shaped room. The switch in the upper-right corner enables or disables the room reflections. "Level" controls the gain of the reflections, "Size" controls the length, in meters, of the room, and "Room" controls the material of the walls, ceiling, and floor, and thus the reflection timbre.

DAW Layout & Workflow

Static binaural is a convenient choice for 3D content mixing because a session can be approached with a very similar workflow to standard stereo mixing. An engineer can create a DAW session, import all required audio signals to independent tracks, and for the most part approach mixing his or her session as normal. But first, there are several nuances to setting up a binaural session that are essential to bear in mind. To illustrate these points, we'll use the static binaural session depicted below as a reference.

Figure 4: Static binaural session example – Pro Tools mix window

This static binaural Pro Tools session contains all the files recorded from a live performance of funk band China Moses at Moods Jazz Club in Zurich, Switzerland. The tracks include vocal, saxophone, synthesizer, piano, bass, and individual drumset microphones. There is also a stereo track for a Neumann KU100 that was placed on stage. Note that the KU100's left input is panned hard-left *with the DAW's stereo pan knob*, while the right input is panned hard-right *with the DAW's stereo pan knob*.

Next, an instance of AMBEO Orbit is placed on each mono track (the KU100 stereo tracks is left alone, because is already exists in the 3D binaural scene). Initially, all mono output tracks in the session will have mono pan pots, but Orbit will convert these tracks to stereo output. The resulting stereo pan pots should be left panned hard-left and hard-right, as with the KU100 track (Note: in DAWs that do not provide stereo pan pots for stereo output tracks, the single pan pot should be placed at *center*).

While there are no hard-and-fast rules for where an engineer may place Orbit in the signal chain, it is generally agreed that the best place is as the very last insert, after all other plugins such as equalizers, compressors, and so on. The track signal can be sent to auxiliary busses either before or after the binaural panner, depending on the intent of the engineer.

Now, the signal can be arbitrarily positioned in the binaural scene with Orbit, adjusting horizontal angle with “Azimuth”, and vertical angle with “Elevation”. For mono sources, the “Width” parameter will be disabled. For stereo sources, this “Width” parameter controls the relative space between the left and right signals in the binaural scene. From here on, the session can be approached with a very similar workflow to traditional stereo mixing.

On the next page, you’ll find a signal flow diagram illustrating a common approach to mixing static binaural music along with the KU100.

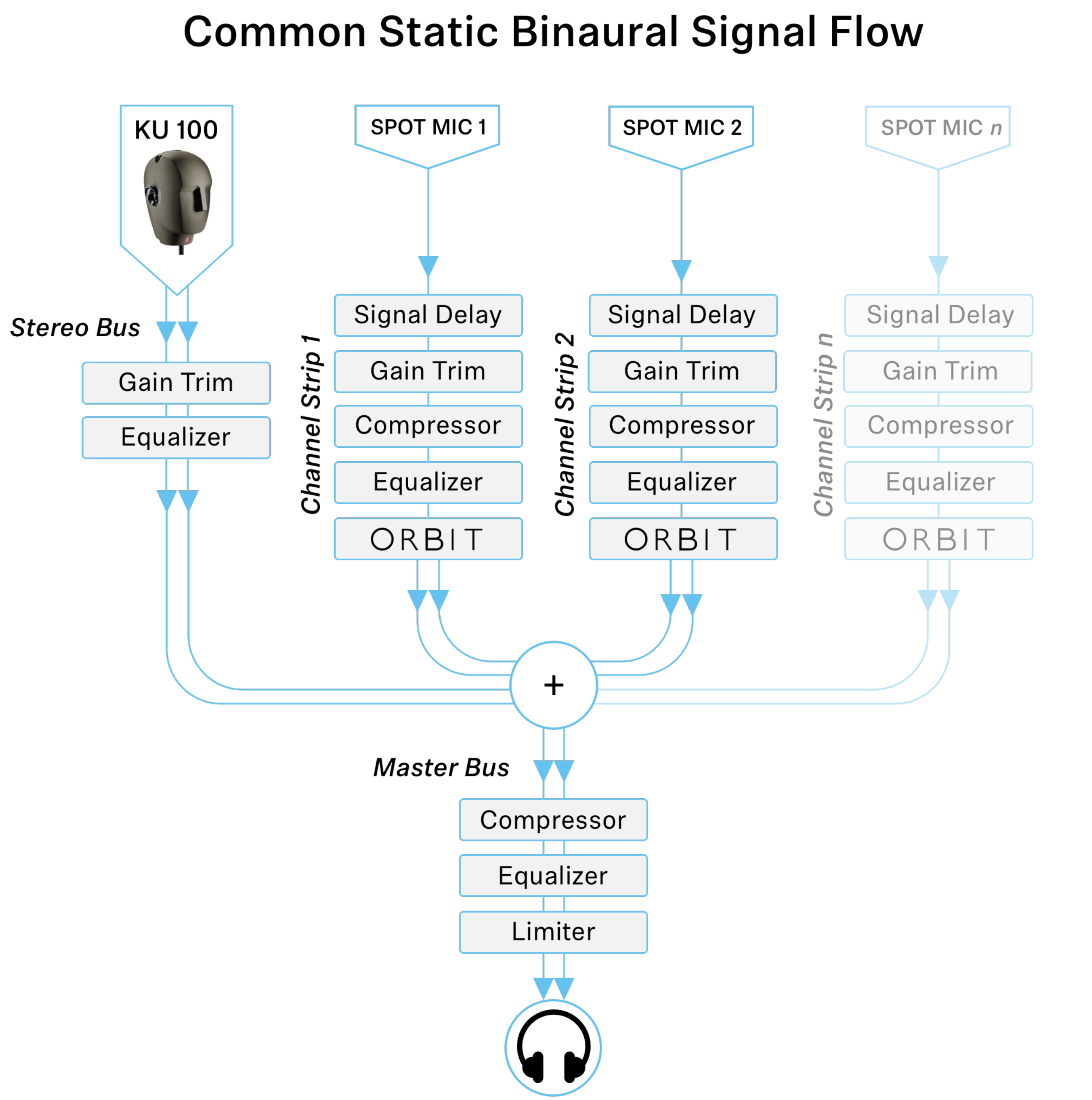


Figure 5: Common signal flow diagram

You will notice that there are certain plugins inserted on the “Spot Mic” tracks that are not necessarily commonplace in a standard stereo mixing diagram. These and other unique features inherent to mixing static binaural audio are explained in depth next.

Common Mixing Problems

There are several common problems specific to binaural mixing that an engineer can face in a session, including:

The HRTF dataset, which has perhaps the most significant impact on the sound of an audio signal chain. As stated previously, when mixing in binaural, you will find that *there is a tradeoff between the positional externalization effect and the tonal preservation of the original signal*. Some HRTF datasets may contain very externalized measurements that give an engineer pinpoint positional accuracy in all three dimensions at the expense of tonal quality, while others may contain measurements that closely preserve the timbre of the original signal at the expense of positional accuracy. Therefore, a mixing engineer's choice of HRTF dataset may be the most important decision he or she makes when designing an audio track's signal path.

Some HRTF datasets are more "externalized", while others are more "tonal". An engineer might consider using a more tonal dataset for audio content that listeners are very familiar with, such as the timbre of an acoustic instrument or the quality of the human voice. Using an externalized dataset for these signals can produce an unnatural or seemingly over-filtered result. In contrast, using a tonal dataset for these signals can still impart the desired localization in 3D, but with minimal negative impact on the tonal quality of the original recording.

For audio content that listeners may not have much experience with for acoustic reference, such as electronic instruments, synthesizers, and effects, using an externalized dataset may not have as much impact on the perceived quality of the result. And for content that needs position to be externalized as dramatically as possible, these datasets can be the best tools.

Before, binaural audio engineers were forced to commit to specific HRTF datasets, without having the option or convenience to blend between filters to craft the sound best suited to their needs. AMBEO Orbit is the only binaural panning plugin available that provides this functionality via the "Clarity" feature.

Additionally, AMBEO Orbit uses the highest-quality HRTF filters, meticulously measured from the Neumann KU100, for optimal fidelity, timbre quality, and localization accuracy. As such, it is the perfect sonic counterpart to the KU100 when mixing in static binaural.

An engineer may choose not to binaurally render a signal. For primary-focus content like the lead vocal or narration dialogue, and for low-frequency heavy content such as kick drum and bass, it can sometimes be useful to forego binaural rendering, and allow the signal to stand out or remain centered in the mix. Additionally, mid/side equalization can be used to remove low frequency content from the binaural scene, the “side”, while isolating it in the center, the “mid”.

Because an engineer has full control of all signal positions in a static binaural mixing environment, ambient information like reverb and auxiliary effects busses can be rendered to cover a certain area of the binaural scene, or not rendered at all. Often reverb busses can sound best when not binaurally rendered, while auxiliary busses containing delays or modulation effects can give very immersive results when binaurally rendered. In dynamic binaural environments, positioning these signals can become much more difficult and prone to breaks in “realism” due to the listener’s freedom of head movement within the scene – with static binaural mixing, this is not a problem.

Many mono-input effect plugins such as delay and tremolo have stereo outputs to widen and expand the signal’s impact in the 2D space. In the binaural scene, these effects can be expanded upon with clever routing and automation to take advantage of the now-3D space. For example, consider a stereo delay: a binaural engineer could route the left and right output of the delay to two separate tracks, each with their own binaural renderer and low frequency oscillator (LFO). The LFOs could automate the position of these delays in the binaural scene, and effectively create a 3D delay with echoes coming from not just left and right, but above, below, ahead, and behind.

Figure 6: Static binaural session example with plugins – Pro Tools edit window

Mixing with a binaural stereo microphone signal: There are several other common issues specific to combining spot microphone and binaural stereo microphone signals that a mixing engineer may face:

- **Delay times** should be taken into careful consideration to prevent comb filtering. Each spot microphone should be delayed by the time it takes sound to travel from the spot microphone to the BSM. This delay can be determined by recording a test impulse (such as a loud click) from each microphone location, measuring the delay in arrival time within the DAW between the particular spot microphone and the BSM, and compensating for the difference. If mixing in post, this delay can be compensated for by simply aligning the tracks correctly in the editor. However, if mixing live (for example over broadcast), a signal delay plugin will need to be employed, such as the Eventide Precision Time Delay (seen in Figure 6), or the Voxengo Sound Delay. It is good practice to calculate a rough estimate of delay mathematically, and then fine-tune by ear.

- **Correlate the spatial locations** of each instrument's spot microphone(s) with their immutable spatial location in the recorded BSM scene. A substantial discrepancy between the location of a source in the BSM scene and the binaurally-rendered placement of its corresponding spot microphone can possibly produce phantom imaging artifacts that jeopardize both the tonal quality of the recording and the localization accuracy. This is particularly evident when musicians move around the stage, and thus the recorded BSM scene as well – ideally any sources that may be perceived as mobile in the BSM scene are also moved accordingly in their corresponding spot microphone's binaural panner.

- **Introduce additional acoustic ambience when appropriate.** For some performances, the dynamic range between different instruments on stage may be significant. The quietest instruments may need to rely heavily on spot microphones in the mix, and exhibit relatively little presence or ambient reverberation in the BSM scene. Thus, additional ambient information may be desirable for these comparatively quiet instruments to sit more naturally and balanced in the complete mix. AMBEO Orbit allows for custom early-reflection simulation in a virtual room, which can be helpful if applied with care to the spot mics of these instruments (taking the acoustic properties of the actual recording location into account). It may be unnecessary or detrimental to apply this virtual ambience to sources that are sufficiently prominent in the BSM scene, however.

- **Matching HRTF datasets with your Binaural Stereo Microphone.** Unlike mixing in conventional stereo, mixing in binaural allows an engineer to create a more realistic and externalized experience of a performance such that the audio is perceived as coming from outside of the listener's head. However, because HRTF filters alter the frequency response of a signal to impart this spatial information, they do ultimately color the sound of the original signal. We have found that despite the more realistic experience of listening to a binaural performance, rapid A-B comparisons between binaural audio and conventional stereo can result in the perception of binaural audio sounding altered or processed. Using a matching HRTF dataset with the BSM, however, such as the AMBEO Orbit's KU100 dataset pairing with the Neumann KU100, can lead to the most natural and pleasing results.

- **Find an optimal balance between spot microphones and the binaural stereo microphone.** Finally, and perhaps most importantly, depending on the nature of the performance the relative volume balance between the BSM and the spot microphones can vary. For instance, an engineer mixing an acoustic singer/songwriter duet performance may rely heavily on the binaural microphone for the overall balance, while using the spot microphones sparingly only to reinforce the vocals. On the other hand, an engineer mixing a funk band may take a completely different approach, relying heavily on the spot microphones for the overall balance, while using the BSM more for the surrounding acoustic context, audience ambience, and sense of space.

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Appendix

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[1] Sun, Liang, Xuan Zhong, and William Yost. "Dynamic Binaural Sound Source Localization with Interaural Time Difference Cues: Artificial Listeners." Research Gate. *The Journal of the Acoustical Society of America*, Apr. 2015. Web. 9 June 2017.

[2] Department of Electrical and Computer Engineering. "Psychoacoustics of Spatial Hearing." *CIPIC International Laboratory. University* of California Davis, 25 Feb. 2011. Web. 09 June 2017.