Headphone Essentials 6:

Interpreting headphone frequency response graphs

Note: this document is part of an instructional series. If you would like to start with more foundational background information, check out the five previous entries.

In *HE4: The Skinny on Headphone Frequency Response Graphs* we looked into the concepts and pitfalls of headphone frequency response graphs in the wild. In *HE5: The quest for a reference (over-ear) headphone* we investigated what an accurate/neutral headphone frequency response looks like. In this episode we'll explore what frequency response graphs tell us about what it sounds like when a headphone graph departs from strict neutrality.

Let's take the Sennheiser HD-600 as an example. This +20-year-old headphone is renowned by many as being almost the definition of a neutral headphone sound. But we see in Fig. 1 that it does both overshoot and undershoot the pale blue neutrality reference curve all along the bass to treble expanse. Now let's look at the same graph but as a recording studio engineer would see/hear it:

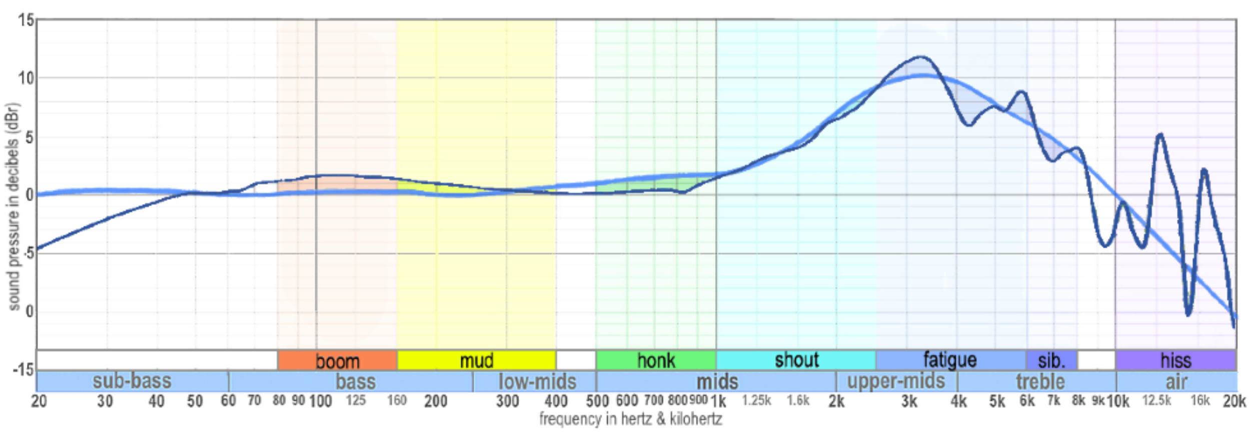

Fig. 1: Sennheiser HD-600 with Oratory Optimum Hifi over-ear neutral target

Note: the mud region actually extends from 100 to 400 hertz. Also, Sib. = sibilance, which is a piercing quality certain vocal sounds, such as S and T, can have when over-loud.

First off, the plunge of the HD-600's frequency response on the far left is rarely an issue, since very little music extends that deep. The largest pipe organs can get down there, synth music can. Even the deepest *basso profundo* human voice doesn't reach that low. But if your music library contains a significant amount of music that is active in that area, the HD-600 and a large percentage of open-ear headphones will disappoint. Equally, very few people over the age of 10 can hear the very highest frequencies on the right, above 17 or 18 kilohertz. And essentially no musical content reaches up anywhere near that high.

Each coloured vertical band in Fig. 1 is a potential auditory problem area. In each case the descriptive label, such as boom or mud, refers to the sound of that area when over-loud compared to the rest of the mix. When there is too little loudness in any given area it's called a *recession*. So the undershoot of the HD-600 from 350 to 1000 hertz is called a mid-range recession. Equally, the overshoot of the reference curve centred at 3.4 kilohertz can be referred to as an upper-mids *elevation*. The thing to keep in mind is the word *potential*. Any given person is a mix of sensitivities and tolerances. For example, many a person finds that a bit of elevation in the boom and mud region tends to impart a welcome extra sense of body to the sound. But for others even a bit of elevation there makes for an unpleasant tubbiness. This sort of person-to-person variation is equally true for all the labeled areas. Once you gain experience regarding which overshoot areas are annoying for you, you'll know what to look for when looking at a frequency response graph for a headphone you're considering purchasing.

Undershoots of neutral are every bit as problematic. They just don't call attention to themselves the way excesses do. For example, the recession in the honk region will obviously make notes played or sung at those frequencies a bit quieter than they should be compared to the rest of the mix. A female vocalist might sound just that much less prominent or further away than she should, while a male vocalist might sound a bit less incisive.

If you look at enough graphs you'll notice that headphone curves past the upper-mids peak tend to be particularly jagged. These are frequencies that result from sound pressure waves that are directly affected by ear anatomy. Ear shapes vary widely. Your own outer ears and ear canals are going to have a different shape than the statistically average ear incorporated into the measurement rig. The further to the right on the graph the more likely there is to be a discrepancy between what your ears do to the sound and what the measuring rig's ear simulators do to it.

If we look at a typical premium model Focal headphone measurement graph like Fig. 2…

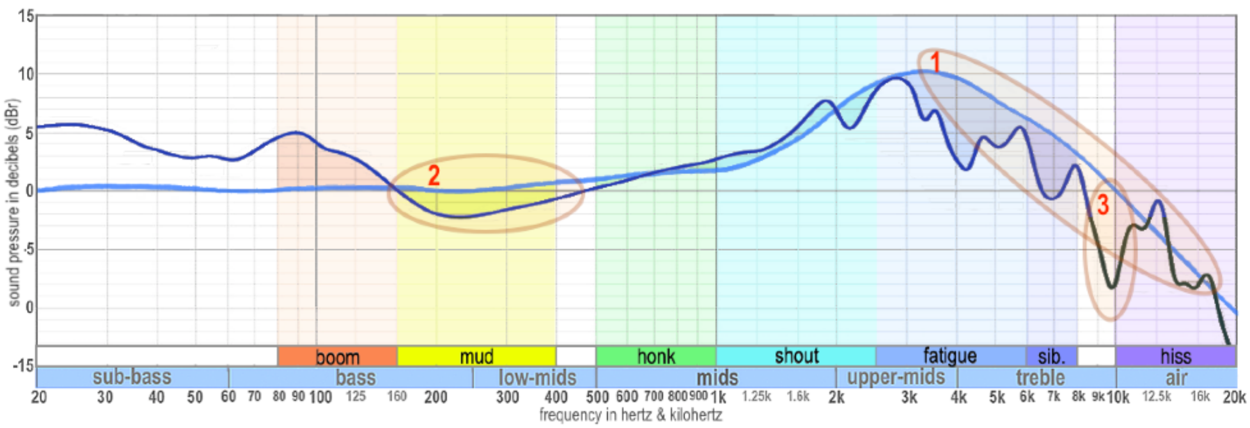

Fig. 2: Focal Celestee

…we see not just that the right side of the graph is jagged (oval 1), but also that it's consistently lower than the target. Very few people are going to listen to a Celestee (that's pronounced sel ess tee, three distinct, un-accented syllables) and talk about spikes or daggers in their ears. Equally, they're missing a bit of clarity, or incisiveness that could potentially be there.

On the other hand, the recession between the 160 hertz line and the 600 hertz line (oval 2) is very common in closed-back headphones like the Celestee. When it's centred on the bass-to-mids transition, or cross-over, like the Celestee's is, somehow it just sounds natural. Similarly, there is a nearly universal dip in the 9 to 10 kilohertz region (oval 3) for both open- and closed-backs. This is apparently an important sound localization feature of most people's ear anatomy and should not be counted as a problem.

Another common recession area is from 1 kilohertz to at least 2 kilohertz (oval 1, Fig. 3), particularly in Hifiman headphones:

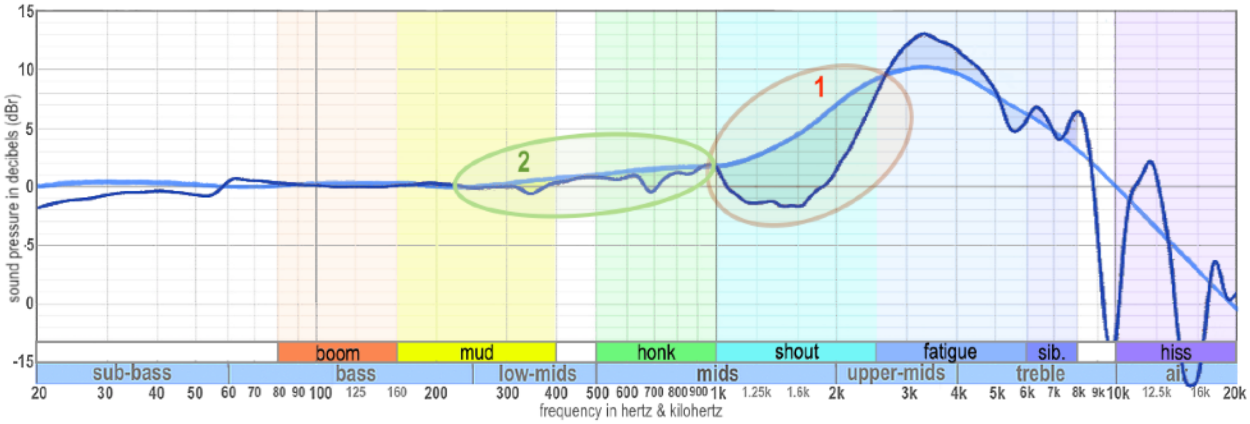

Fig. 3: Hifiman Ananda

Many find this creates a bit of extra sound stage perception, but it does so at a cost. It tends to create a certain lack of a sense of immediacy or presence to voices and instruments.

The biggest and most common departure from neutral is of course the bass bloat we see in so many headphone FR graphs. When well done, as it is here in this Beats headphone (oval 1, Fig 4)…

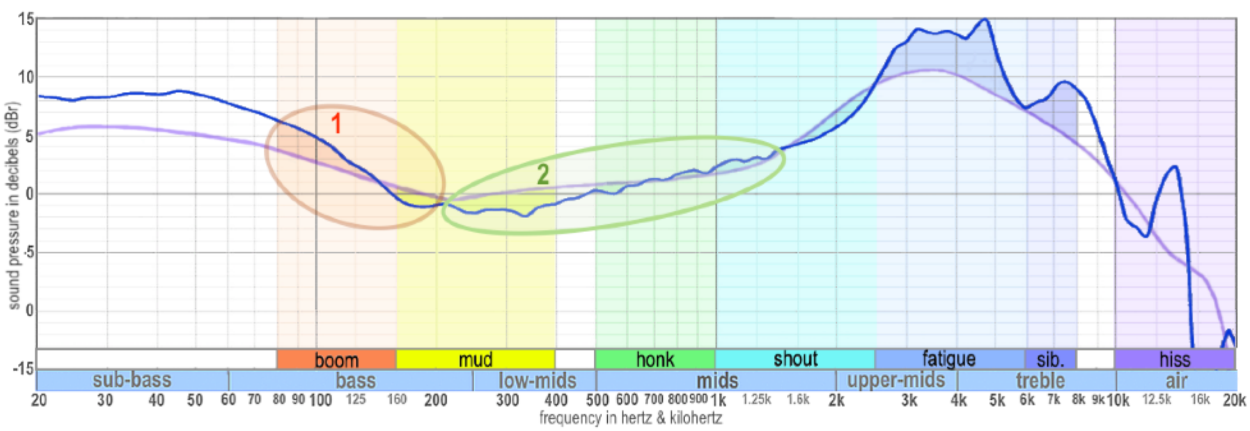

Fig. 4: Beats Solo Pro (using alternate Harman reference curve in purple)

…we get plenty of bass quantity but importantly, it drops off before the mid-range starts. By doing so it does no harm to the important mid-range, which is nicely shaped for excellent vocal and instrumental presentation. (The elevation on the right side of the graph is equally interesting. I suspect it's there to discourage people from listening too loudly and thereby heading toward tinnitus).

To the right of the bass region the Harman 2018 over-ear reference curve shown in Fig. 4 is essentially the same as the Oratory Optimum HiFi curve we've been using above. But the Harman curve's bass shows the majority consumer preference in bass quantity, crucially with the tapering off happening before the mid-range begins. (The Harman curve could equally have been used for the Celestee graph, depending on your personal preference.)

A bass bloat gone wrong looks like this:

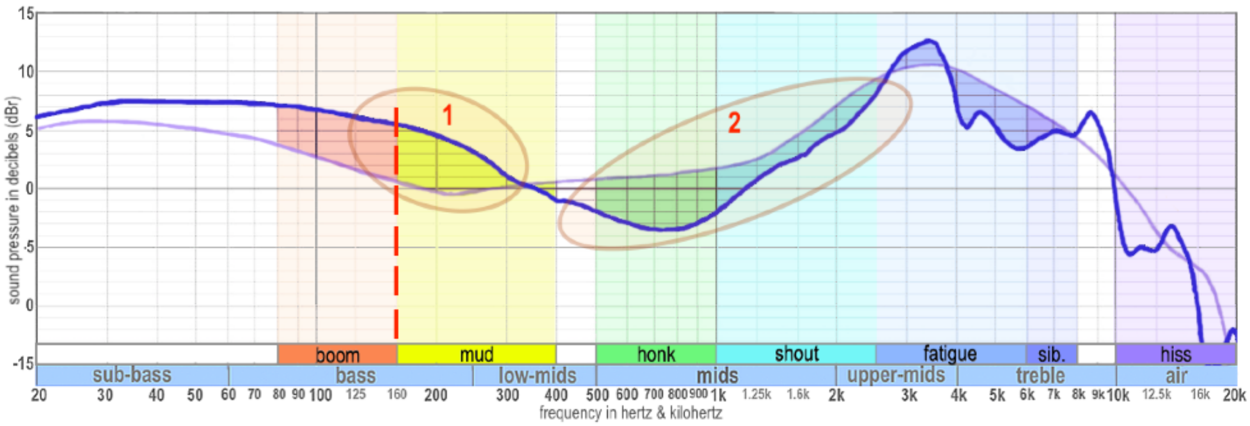

Fig. 5: Beats Solo 3 Wireless

Here, the bass drop-off does not arrive until well past the bass-to-mids transition (oval 1, Fig. 5) and then is followed by a serious recession in the honk and shout areas (oval 2). This sacrifices the very heart of melody territory for the sake of total domination by the forces of thump and slam.

Another distinguishing characteristic of headphone graphs is the degree of smoothness or choppiness along the measurement line. We've seen that large up/down swings in the high frequencies are simply a by-product of human ear anatomy. But that isn't the case in the bass and mid-range. If we look back at the Beats Solo Pro and the Ananda, we see a fairly fine-grained waviness in the heart of the mid-range (green oval 2s, Figs. 3 & 4). This has to have some consequence for sound quality — most likely fairly subliminal — but I haven't heard it discussed, and I don't have experience with a sufficient number of headphones to have formed an opinion of my own.

All of the above hopefully gives the basic idea. But in reality, as stated we all have our preferences and sensitivities. A rock and metal enthusiast might well want at least as much bass as shown in the Harman curve — but also strongly prefer less of an overall ear gain region rise (reduced upper mids) to save wear and tear on his nerves from the screech of electric guitars played at max volume. For such a person the curve he should use as reference would look something like this:

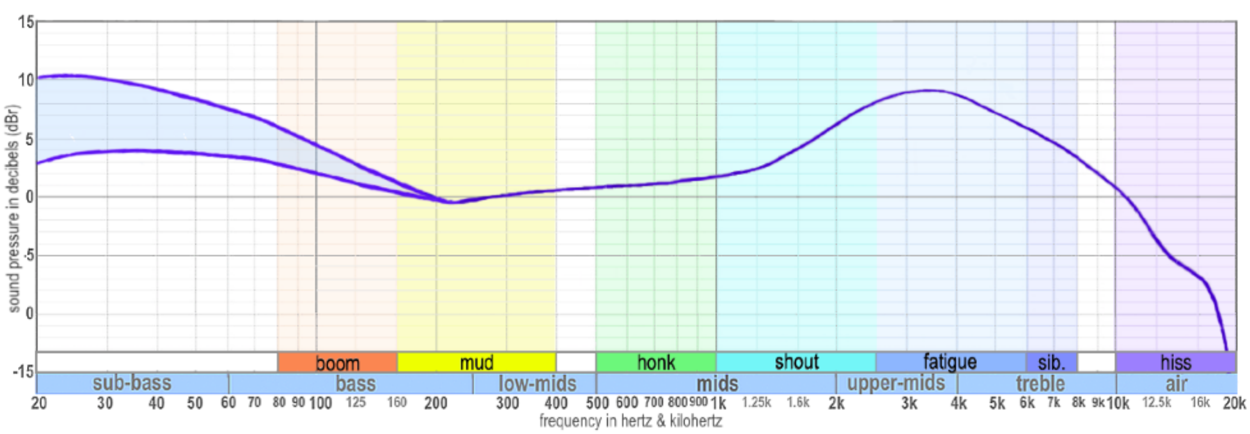

Fig. 6: example personal preference curve

So this person would evaluate the Focal Celestee like so:

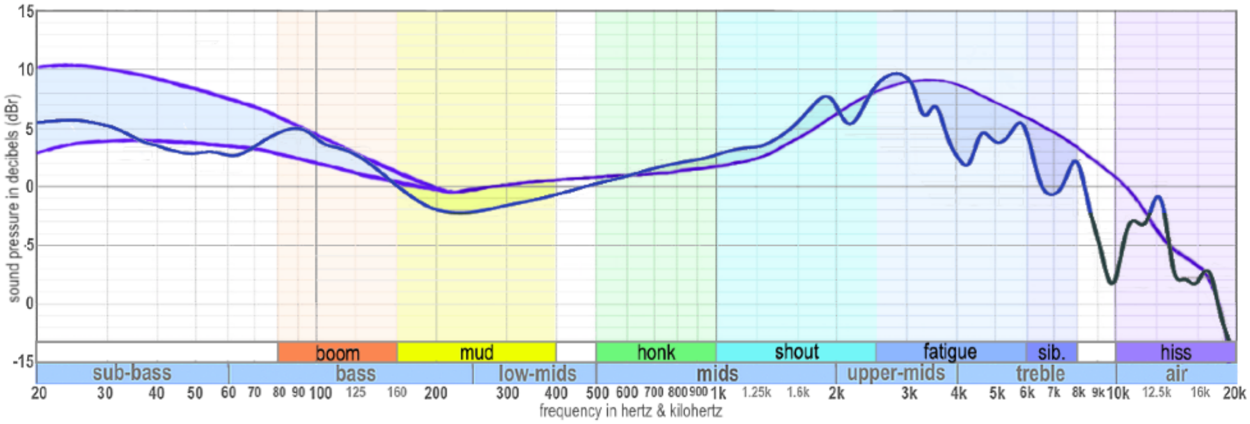

Fig. 7: Celestee compared to Fig. 6 preference curve

And even then the recession in the upper-mids and treble might not even be a show-stopper given this person's genre preferences.

In closing, it's time to emphasize that frequency response is not the be-all of headphone sound production. Instead, it's more like the starting point. If a car doesn't have four round wheels sporting road-worthy tires, it's not going to serve much purpose. But once that's assured, then it's time to look at the engine, the passenger area, handling, mileage, etc. I cover the basics of the headphone equivalents, such as dynamics, detail, sound stage and imaging in the earlier unit *HE2: the basics of headphone sound*. What's missing is an objective basis, such as frequency response graphs provide, with which to analyze these equally important aspects of the headphone sound signature. Which means that, short of buy-and-try, most of us are lost in a sea of highly conflicting subjective reportage.

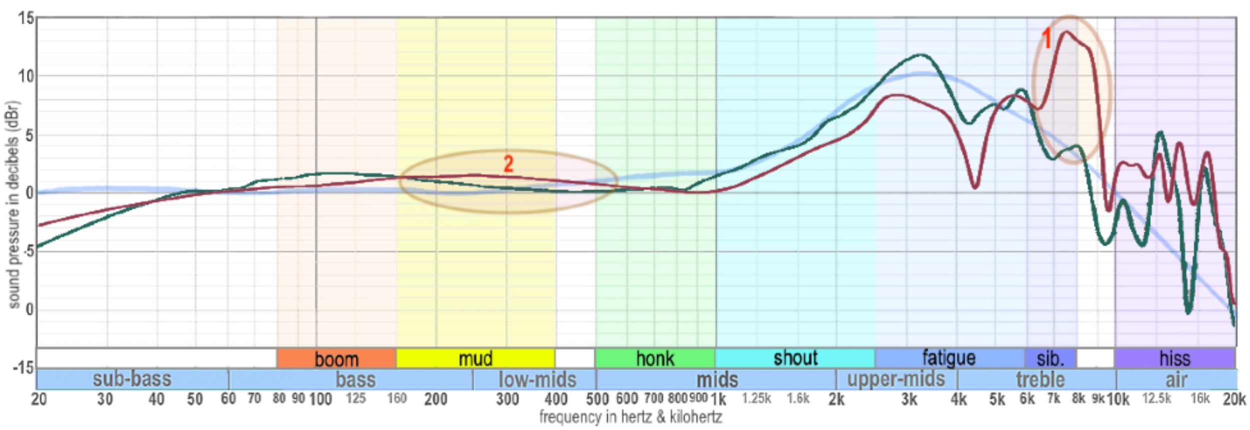

Fig. 8: Sennheiser HD 600 and beyerdynamic DT 1990 PRO

For example, I own both the beyerdynamic DT 1990 and the Sennheiser HD 600. To my ears the HD 600's frequency response is preferable, but not for the usual reason. For a person with an 7 or 8 kilohertz treble sensitivity, the DT 1990 (oval 1, Fig. 8) isn't even in the running. For me, that spike is barely perceptible, yet the seemingly slight excess in the mud region is a show-stopper without EQ.

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And that concludes this episode as well as the non-specialized entries in the Headphone Essentials series. The next two entries delve into the controversial subject of headphone equalization. As we've amply seen in this exploration, headphone sound design is so fraught with compromises that you're unlikely to perfectly match your own hearing without EQ. So if interested proceed to: *HE7: A parametric EQ primer* or *HE8: Trying to make do with 10-band EQ*.