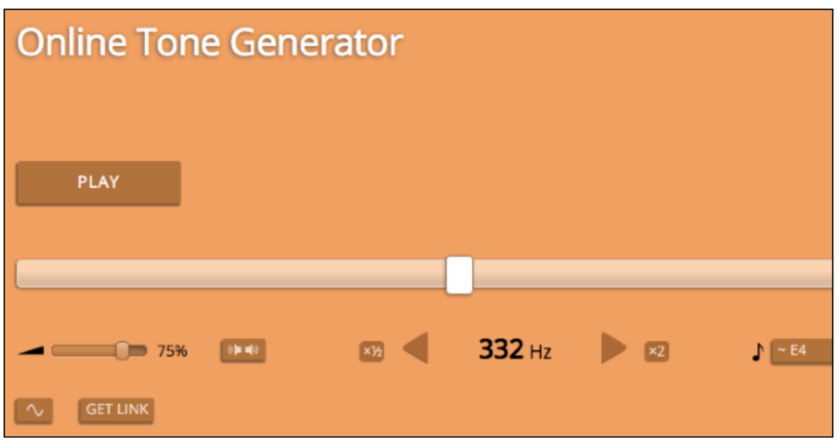
Headphone Essentials 4:

The Skinny on Headphone Frequency Response Graphs

Note: this document is part of a instructional series. If you would like to start with more foundational material on the nature of sound, see *Basics of Musical Sound* and *Basics of Headphone Sound* at Headphone Essentials.

If you are reading this document, you are likely interested in finding a headphone that matches your listening preferences. The single most important factor for many is the headphone's frequency response (FR). This is often called its tuning or tonality. Other factors, such as its dynamic responsiveness, sound staging, imaging and detail reproduction are also important considerations. But if the tuning is not agreeable those other factors are not likely to rescue it.

Getting started



To get started go to the Online Tone Generator in your browser. Make sure the volume on your computer is initially set to a fairly low level, then press the space bar once to turn sound on, then move the slider fairly slowly and evenly left and right. If the sound does not change in loudness (except for tapering off at both extremes) you're hearing what's called a subjectively flat response. If it grows louder and softer as you move the slider, that's a non-flat response. If possible, you may want to try this with more than one headphone or speaker to see how they vary (remembering to start at a low loudness level with each one). (By the way, as is typical of tiny speakers, the one built into my laptop doesn't produce any sound at all to the left of about 100 hertz.)

Now let's say we want to make note of what we're hearing when sound is being produced by a particular pair of headphones. Let's say we start at the far left and hear nothing until maybe 22 hertz. Then we hear it gradually getting louder until 67 hertz, then quickly getting quieter until 83 Hz, then starting to climbing again. We might draw a line like so to represent this:

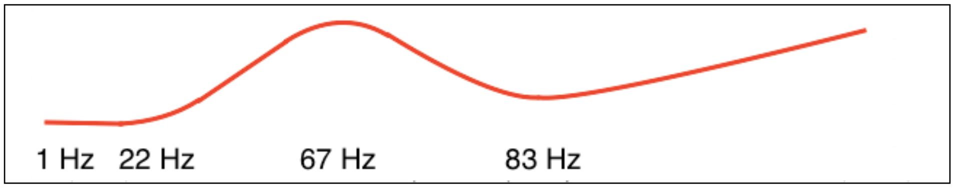


Fig. 1: freehand loudness line

What we're intuitively doing is recording the hertz numbers from left to right, just as they appear when we move the slider from left to right. Plus, we're showing the change in loudness as an up and down movement. And that's all there is to a frequency response graph:

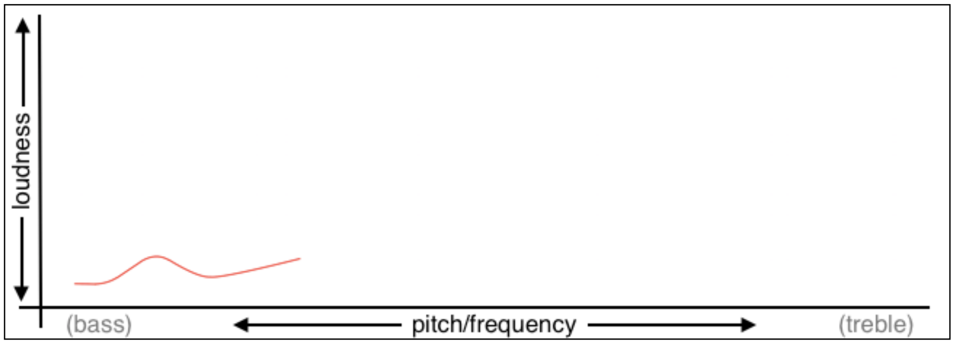


Fig. 2: frequency response graph axes

We can see that if we want to record the actual hertz numbers (abbreviated as Hz) we would need a very long graph from left to right, since the hertz numbers go from 1 to 20,154. The math trick to deal with that is to use a logarithmic scale. This simply means the distance keeps getting shorter as the numbers keep getting larger:

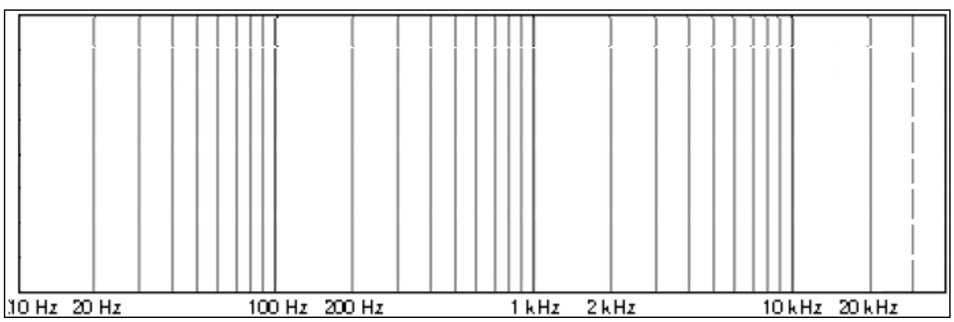


Fig. 3: frequency response graph with logarithmic hertz scale

Fig. 3 has a logarithmic scale from left to right. From 10 to 100 there are guide lines on the tens. From 100 to 1000 they're on the hundreds. From 1000 to 20,000 they're on the thousands. Notice that for convenience we use the kHz notation to get rid of the increasingly large number of zeros, so 1 kHz = 1000 Hz. The scale concentrates on the range of 20 to 20,000 Hz since this is the range of human hearing. (Keep in mind that the highest frequency you can hear decreases gradually with age. So 20,000 Hz is highly optimistic.) Also notice that the distance between 10 Hz and 100 Hz is exactly the same as the distance between 100 Hz and 1000 Hz. And both are exactly the same as the distance between 1000 Hz and 10,000 Hz.

That takes care of the left/right scale. For up/down we can use logarithms again. But the units we need for loudness are notated as dB, which stands for decibels. For our purposes, the absolute values don't matter. We'll use a scale with an arbitrary starting or 0 point as a baseline and simply indicate the degree of distance from that particular loudness, either louder or quieter in decibels:

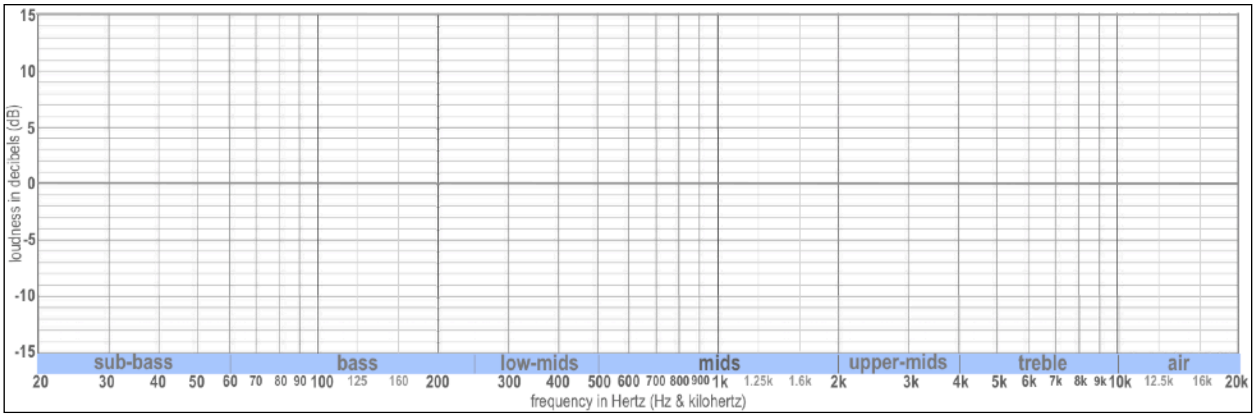


Fig. 4: frequency response graph with decibel loudness scale

Any six decibel change going upward doubles the sound pressure, which roughly correlates with loudness, and any six decibel change going downward halves it. A one decibel change is about as fine a discrimination as we humans can reliably make. This might seem like an improvement until we actually try to use it. We can get exact frequency numbers from the Online Tone Generator. But how do we judge how high or low to place each loudness value with any degree of accuracy?

Measurements done right

For this we need some fancy, technical, and expensive measuring equipment ($20,000+ is not uncommon) to achieve reliable results. Fortunately, there are several good samaritans doing such measurements and posting them on the web. One example is acoustic engineer Oracle1990. Here's Oracle1990's measurement for the still-popular Audio-Technica ATH-M50x headphone:

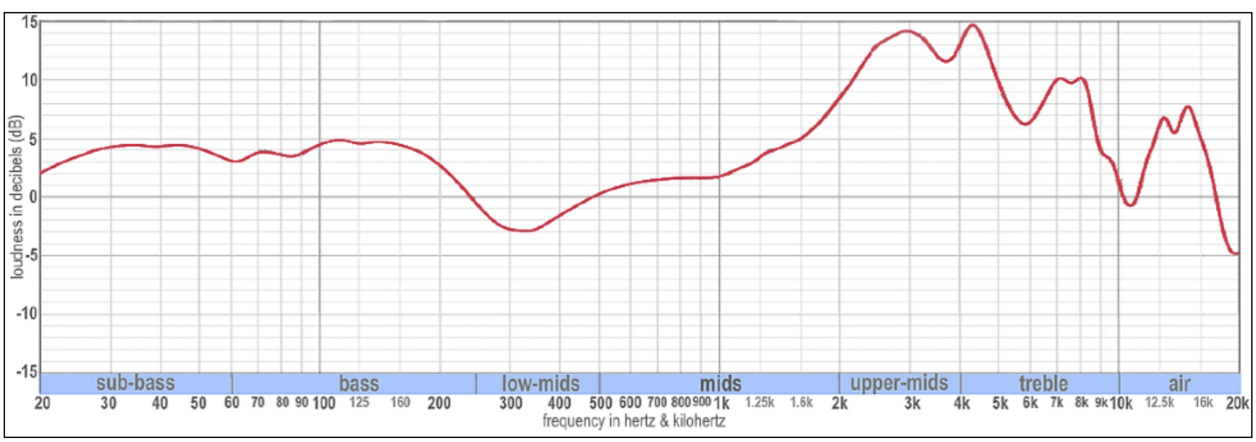


Fig. 5: Oracle1990 FR graph for the Audio-Technica ATH-M50x

Unfortunately, there's a slight gotcha. The red line shows changes in loudness going across the human hearing range of frequencies. But, since it shows actual measurements, the line is much more of a jagged rollercoaster ride than your ears would lead you to believe. Also, our ears and brains are designed to hear the faintest possible sounds that are critical for survival. The peculiar shape of our ears are in fact natural amplifiers for high frequency sounds. When we factor in the acoustics of the enclosed spaces in which music is typically made and heard we get:

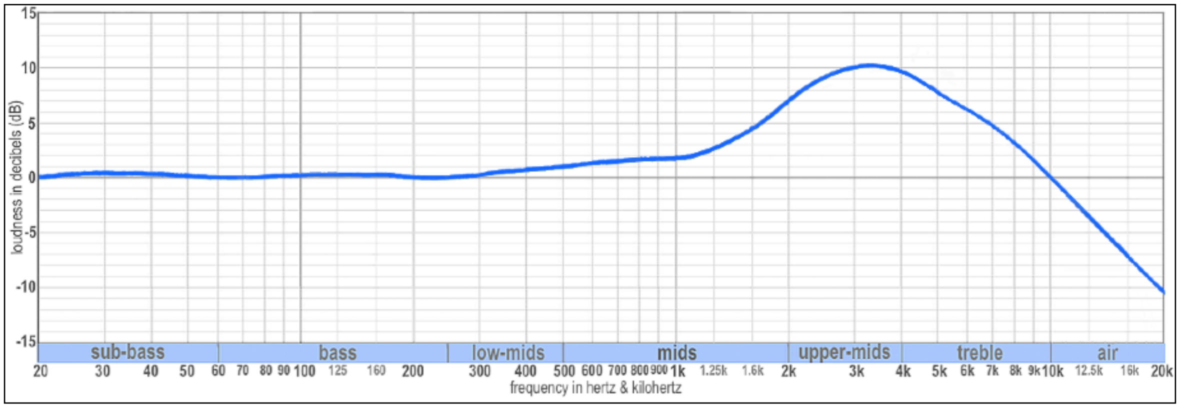


Fig. 6: Oratory Optimum HiFi over-ear headphone neutrality curve

Simplistically, a headphone that exactly re-produced this measurement curve would produce a perfectly even, or flat-line, sound if we used it to listen to the Online Tone Generator (dig deeper here). In other words, our brains would translate the curve shown in Fig. 6 into the subjective "curve" shown in Fig. 7:

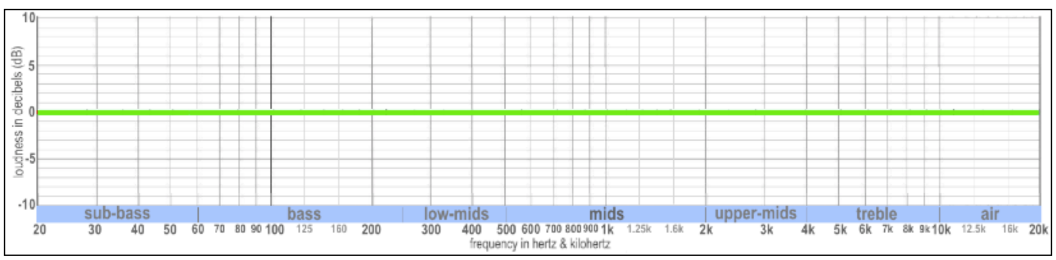


Fig. 7: subjective experience of a perfectly even loudness across the frequency range

If we overlay the curve from Fig. 6 onto the M50x measurements of Fig. 5 we get:

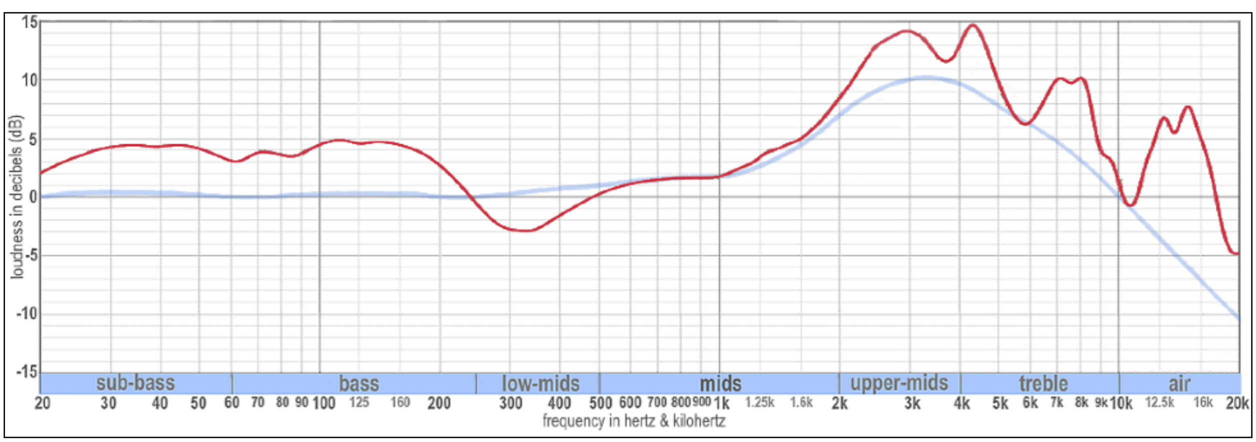


Fig. 8: ear amplification (red) vs M50x frequency response (blue)

The sheer number of ups and downs in Fig. 8 may look like a problem. But it's actually about average for today's headphones (especially if they're a closed-back design like this one is). Our ears can't easily distinguish small up/down changes, and manufacturers simply don't have the technology to do better. Most often smoothing out a frequency response irregularity results in a loss of some other equally important acoustic quality, like dynamics or sound stage.

What we should hear if we use a pair of M50x to listen to the Online Tone Generator is an increase in loudness where the red line climbs above the cyan line. Plus, we should hear a decrease in loudness wherever the red line drops below the cyan line.

Another source, especially for measurements of lower-priced headphones, is Rtings.com. Here's their measurement presentation for the M50x:

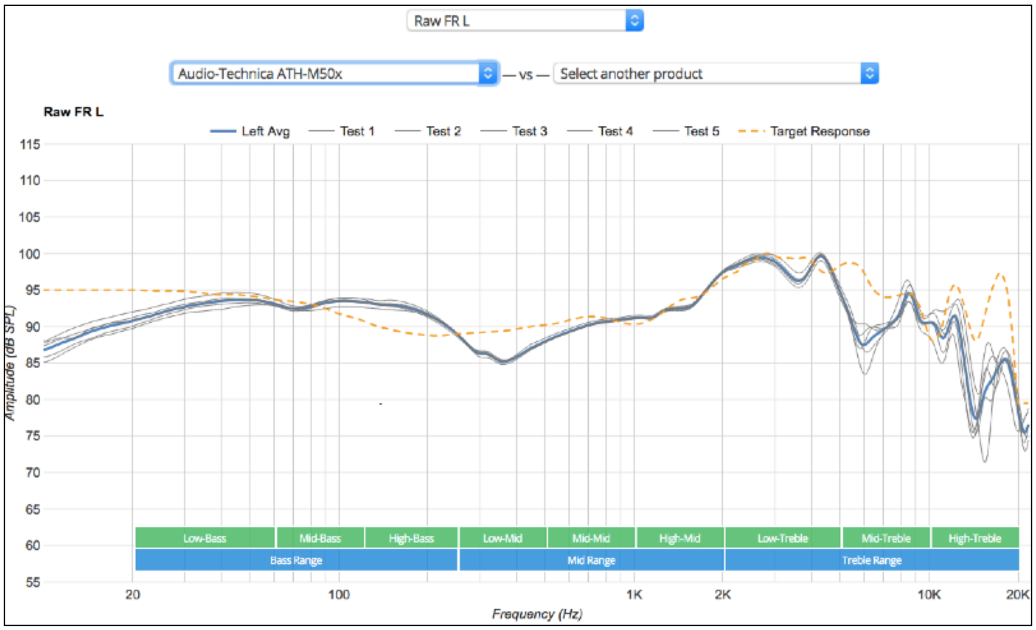


Fig. 9: rtings.com measurements for M50x

One difference is that Rtings show measurements between 10 and 20 Hz on the far left. Mostly, we would perceive these as vibrations rather than sound. Another difference is the dotted orange line. This is their version of a common target for an ideal headphone sound response (Harman 2018) as adapted to their measuring equipment.

A third site with a large collection of measurements is Crinacle's In-ear Fidelity. Two other sites have significant collections of quality raw FR measurements: SoundStage!Solo, Headphonetestlab. Also, Resolve Reviews has recently started doing measurements which can currently be found scattered about the forum of headphones.com.

Finally, there is an older site, sadly now defunct, but the extensive collection of measurements are happily available on Stereophile. These measurements are in a PDF for each headphone and look as shown in Fig. 10. The FR graph is upper left. But confusingly it contains two sets of lines. The lower, grey lines are multiple trials of measurements for the headphone moved slightly for each one. (All competent technicians use the same multiple-trial procedure, only showing the average of the trials.) But the red and blue lines above the grey lines show the average of left and right channels separately. They are also adjusted for the properties of the measurement equipment by comparing them to a now-obsolete target response.

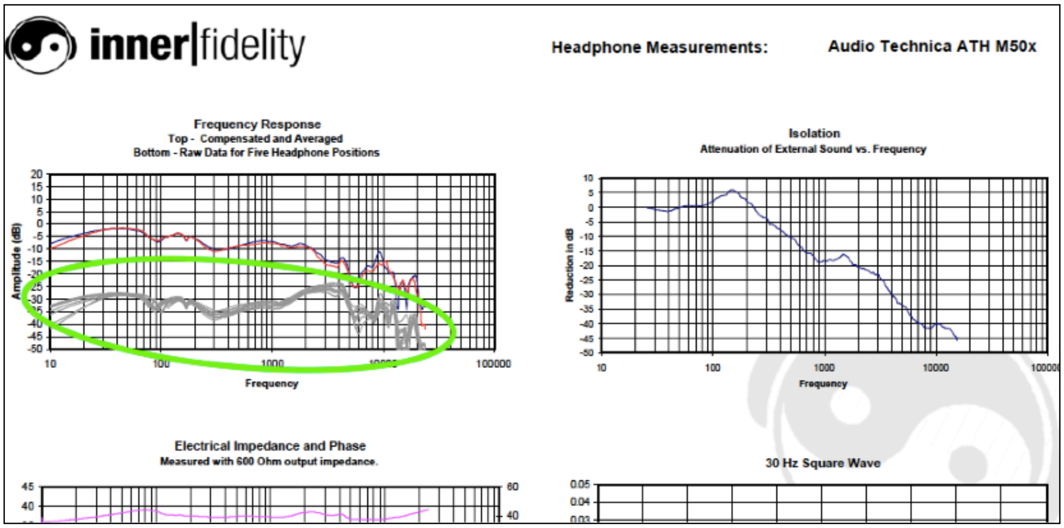


Fig. 10: innerfidelity.com measurement page for M50x, frequency response circled in green

At this time many of Oratory1990's headphone measurements have yet to be duplicated on the Headphone Database site. You can find the others on his reddit EQ page embedded in the PDF page for each headphone.

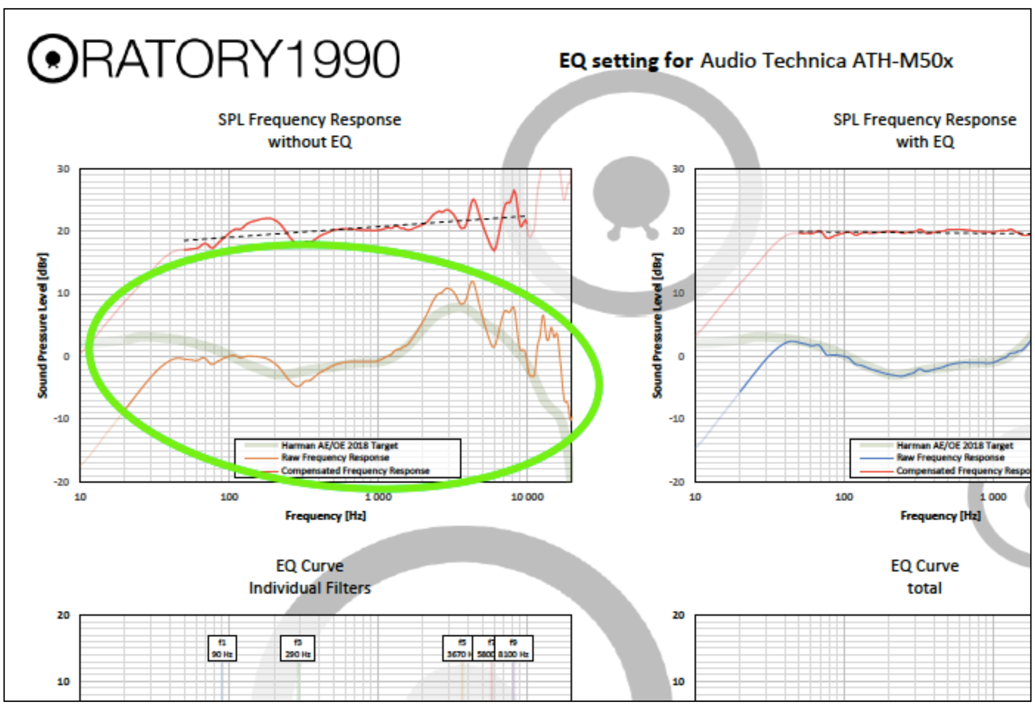


Fig. 11: Oratory1990 EQ database page for M50x with FR graph circled in green

Oratory1990 uses the gold standard GRAS 45 measurement equipment. This includes not only a highly realistic simulacrum of a statistically adult average human ear. But also the ears are mounted in a mannikin-like head which facilitates achieving a consistent and repeatable signal from both ears. Crinacle, Brent Butterfield of SoundStage!Solo, Keith Howard of HeadphoneTestLab and Resolve Reviews are using some permutation of the somewhat less expensive GRAS 43 measurement rig. This employs a single copy of the same ear simulator used in the GRAS 45, requiring the technician to attempt to achieve the same clamp force, etc. when measuring both sides of a headphone. Rtings and InnerFidelity use an older HeadAcoustics set-up which gives similar but less accurate results.

Fig. 12: random human ear photos (from Wikimedia Commons)

The GRAS ears are notable for more accurately representing what a hypothetically *average* human ear would hear, based on an international standard. Yet look at a half dozen different people's outer ears to see just how far we all depart from the norm, and ear canals vary as well.

So the best measurements are the ones that most closely match the total acoustic signature of your own ear anatomy. A straight cylinder may not look like a human ear canal, but it may result in measurements that come closer to matching your particular ear response than the statistically averaged GRAS ear does. The only way you can make that determination short of purchasing headphones and comparing involves some considerations that will be discussed in later documents in this series.

Until then, measurements from the other sites are still plenty useful. Often measurements of a particular headphone won't be available on any site, let alone on the site you prefer. The trick is to only compare the measurements on a given site to the other measurements on that site.

Measurements done less right

The above are competent and useful sources of information. On user forums, however, you'll encounter measurement graphs done by amateurs using inexpensive equipment.

As a point of comparison, here are Oratory1990's measurements for the AKG K371:

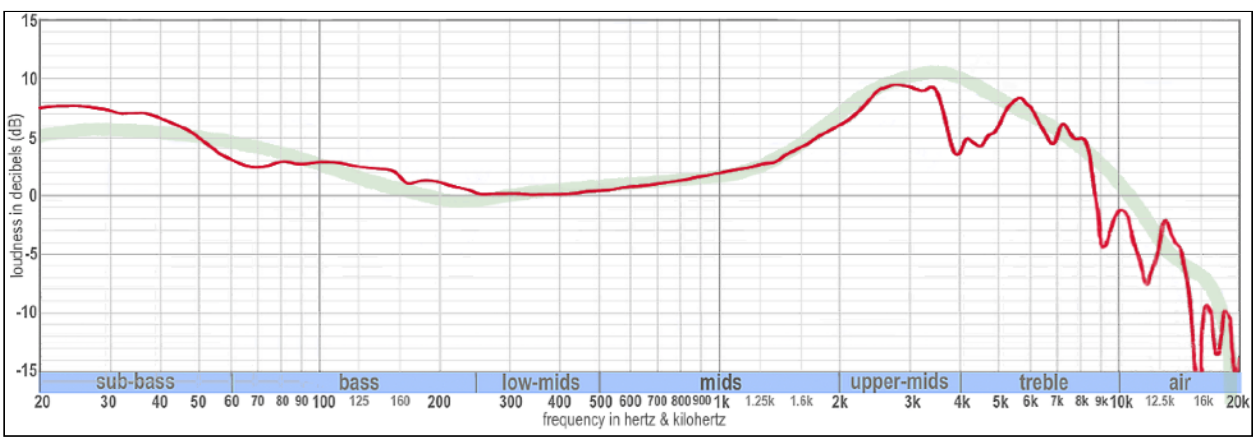


Fig. 13: Oratory1990 FR graph for AKG K371

This headphone was designed to reproduce the Harman Target frequency response (pale green curve) as closely as possible. As we can see it does so admirably. Now here is an amateur measurement of the K371 that I found by using Google:

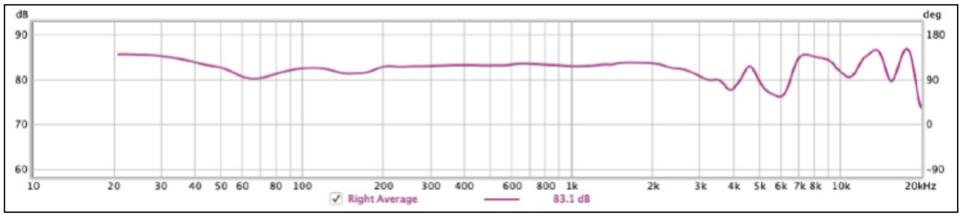


Fig. 14: MiniDSP EARs frequency response graph for AKG-K371

This was done using an inexpensive and popular tool called the MiniDSP EARs. We may scratch our heads as to how to relate the purple line in Fig. 14 to the orange line in Fig. 13. They both claim to show the frequency response of the same model headphone. The first thing we need to know is that we're not seeing the actual data in Fig. 14. What we're seeing is a plot of the *difference* between the actual measurements and some unspecified target response curve. And target curves vary all over the proverbial map. The graphs we've been looking at previously are what's called raw or uncompensated. Fig. 14 is called a *compensated* FR graph. Yet it makes no mention of that fact, nor of what target it's compensated to.

Understanding compensated frequency response graphs

Let's start with a frequency response graph including measurements and a target response curve like the one by Oratory1990 of the AKG K371 in Fig. 13 above.

Now that you've dived down the frequency response rabbit hole the odd and squiggly lines are starting to make sense. But for anyone else the graph is meaningless, not to mention off-putting, as well.

First, we'd have to explain that left to right means low-pitched to high-pitched sounds and top to bottom means loud to quiet sounds. Then we'd have to say that the orange line shows how this particular headphone changes the loudness of the sounds being listened to, making sounds at some frequencies louder than they actually were and making other frequencies quieter than they actually were. Then we'd have to explain that the human brain actually expects some frequencies to be louder than others, which is represented by the green line. So we're supposed to pay attention to the differences between the green and orange lines.

The green target response line is typically supposed to show how much physical loudness (sound pressure) it takes for our brains to perceive subjective equal loudness. We can make this a little easier to digest if we flatten out the green line and have the orange line tag along for the ride. In other words imagine the green line is a string and we pull the string taut so the green line goes from wavy to straight. Fig. 15 is an Oratory graph showing both the raw and compensated versions of the same measurements. Notice that the relationship between the green and red lines is identical in both cases, but the green line has been flattened. I added arrows to show where we'd have to press on the raw green Harman curve to morph it into the straight line of the compensated version.

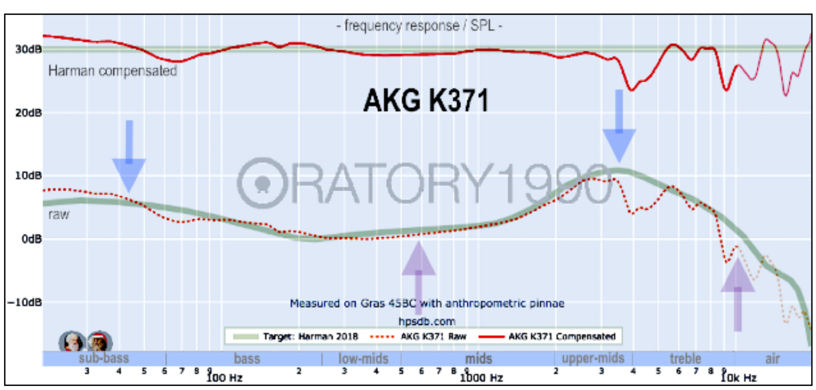


Fig. 15: AKG K371 graph morphed to straighten the Harman curve

Now let's return to my scathing critique on how compensated graphs are typically used.

The MiniDSP EARs tool comes with two different target response curves. One, called HPN (headphone neutral), is somewhat similar to the diffuse field curve. The other, called HEQ (headphone equalization), is somewhat similar to the Harman Over-Ear Target. Given the relative flatness of Fig. 14 we can make an educated guess that the HEQ curve was used. But that information is rarely provided. Here I've over-laid the MiniDSP EARs graph on top of the Oratory1990 GRAS 45 with Harman 2018 compensation graph from Fig. 15:

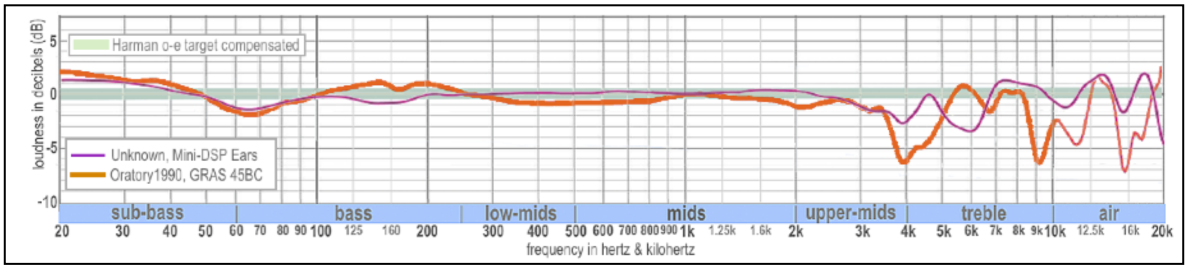


Fig. 16: compensated graph comparison: MiniDSP EARs versus GRAS 45BC for AKG-K371

As we'll see below, this is by no means a bad match-up. The main discrepancies start around 2 kilohertz, which is typical and corresponds with similar variations between human ear responses. But we still don't know how closely the MiniDSP EARs HEQ target response curve matches the Harman target curve. So the graphs might be even more closely aligned if both measurement rig results were compensated with the same target response curve.

Here's another MiniDSP EARs graph of the K371:

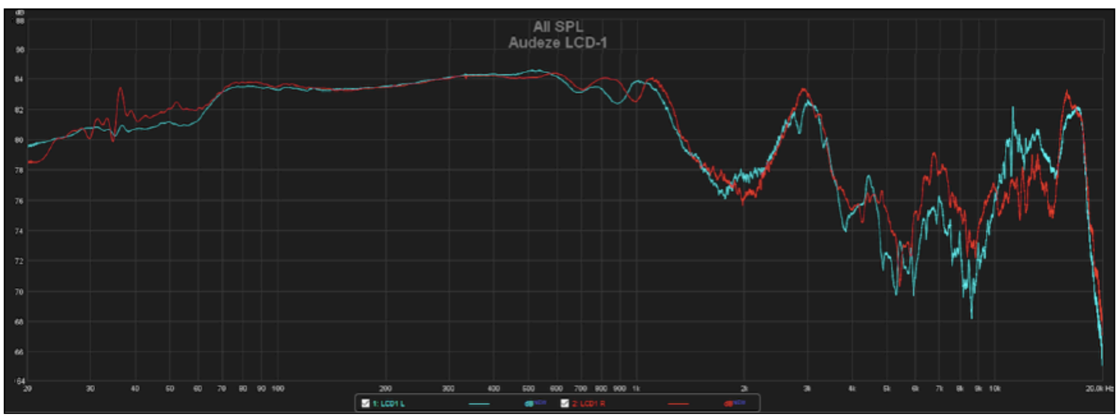


Fig. 17: Metal571 MiniDSP EARs FR graph for AKG-K371

This one was done by YouTube headphone reviewer Metal571. Metal is a careful and thoughtful guy. He makes sure to tell us that the MiniDSP EARs graphs are seriously limited (especially in the region around 4.5 kHz). He also makes sure to tell us that he's using the HPN compensation. (Don't be confused by the dramatic black background. That's purely cosmetic.) The overall downward slope of the measurement curve is due to the increasing difference between the diffuse field ear gain curve and the Harman Target curve in the ear amplification area above 1 kHz.

But another major difference between the two MiniDSP EARs graphs, Fig. 14 and Fig. 17, is the vertical scale. In Fig. 14 each horizontal reference line is 10 dB above or below the next. In Fig. 17 they're only 2 dB apart. In consequence, Fig. 13 tends to downplay the rises and falls of the measurement curve. Fig. 17 highly exaggerates them.

This scaling effect can be used to great effect to put a headphone in a good light. The headphone forum Head-Fi.org occasionally produces FR graphs of headphones released by sponsoring companies. The Head-Fi measurement equipment is the same as Oratory1990's and they know how to use it.

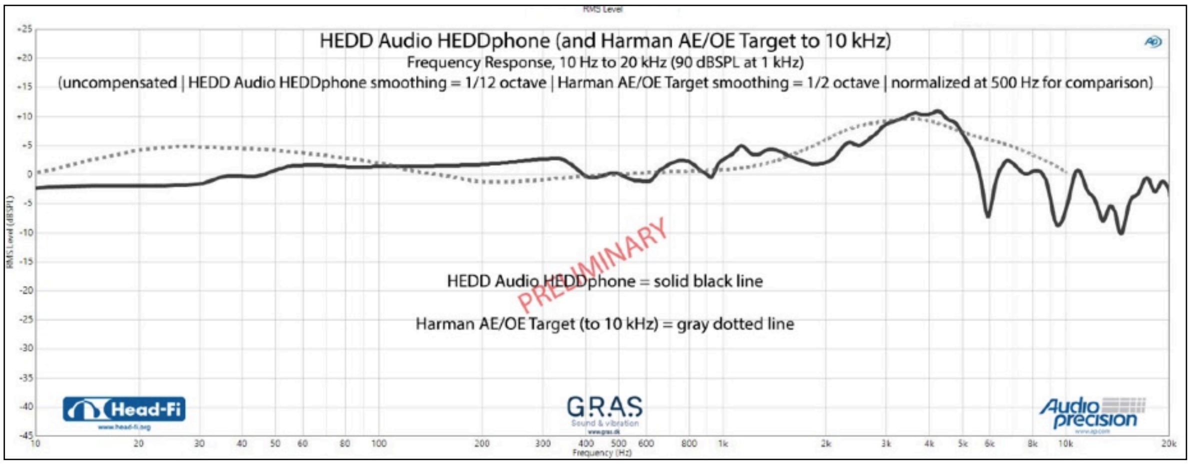


Fig. 18a: Head-fi measurements for the HEDDphone

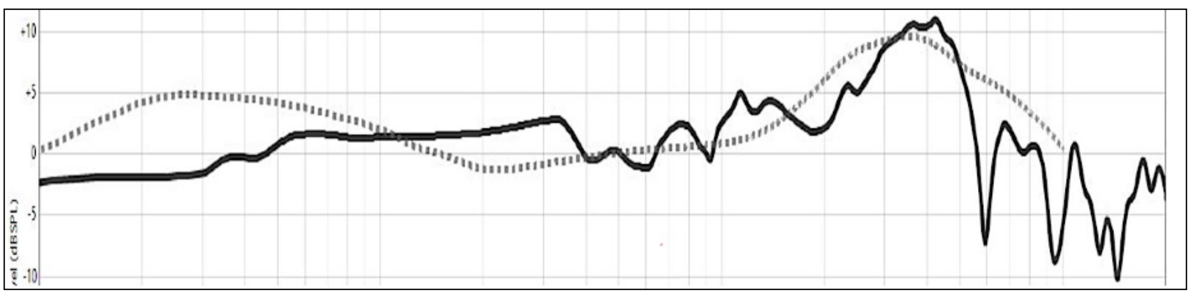


Fig. 18b: Fig. 17a vertically re-scaled

The graph in Fig. 18a is directly from the Head-Fi website. This particular headphone sells for $1900US as I write this. The solid black line are the raw measurement data. The dotted black line is the Harman Target. Notice how shallow the Harman curve is compared to what we're used to from the green line version in Oratory1990 graphs. For the graph in Fig. 18b I've simply taken the original graph and stretched it vertically so the horizontal reference lines are now a more typical distance apart. The dotted Harman Target curve now looks familiar. Same data, dramatically different presentation.

The small print in the Head-Fi graph legend says the data are presented with 1/12th octave smoothing. This was frequently done. It simply acknowledged the limitations of even the best measuring equipment and measuring techniques of the not too distant past. Applying it to GRAS results is less appropriate. We may not be able to identify small variations, but we can perceive them as graininess. From time to time you'll see FR graphs with even smoother measurement curves, even as extreme as 1/3rd octave. When the graph line looks smooth and simple, be suspicious that more aggressive smoothing has been done.

In short, it's the wild west out there in the land of headphone FR measurements and their presentation. We have to be wary of:

- Amateur-grade test equipment
- Unspecified compensation curves applied to the data
- Loudness scale compression applied to the data
- Excessive smoothing applied to the data.

Do good measurements agree?




Even if we choose to focus our attention on the quality measurement sites for frequency response graphs that doesn't mean their results are completely interchangeable.

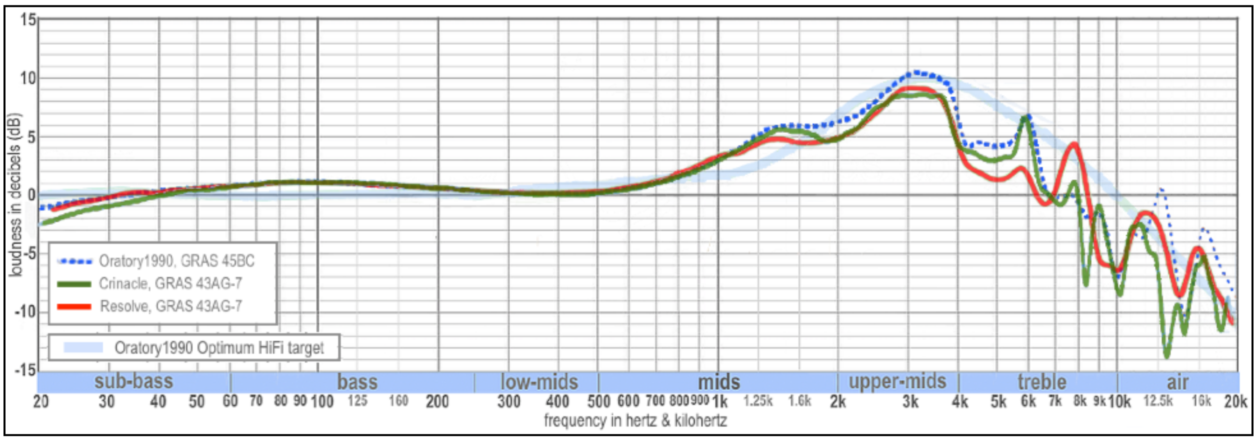


Fig. 19: three-way comparison of GRAS measurements of the Focal Clear headphone

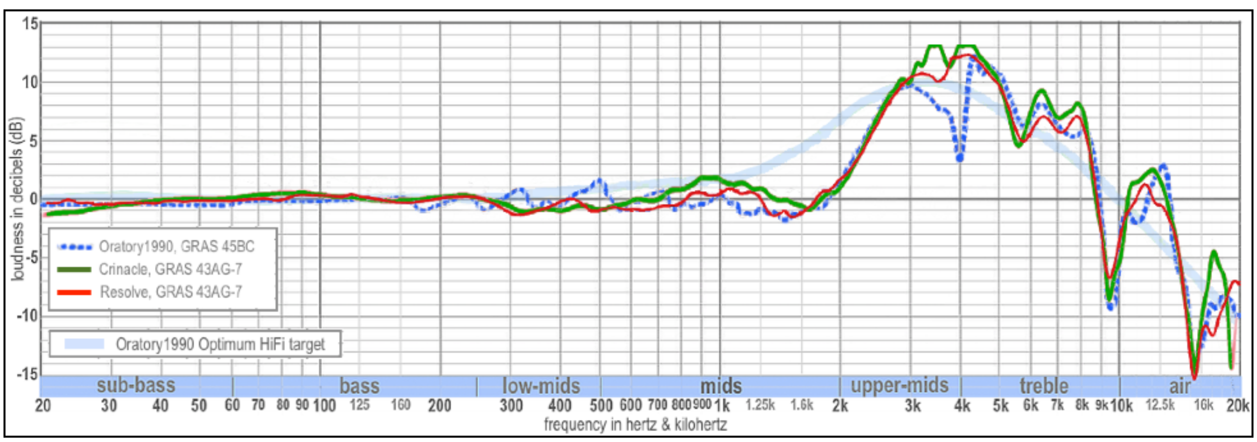


Fig. 20: three-way comparison of GRAS measurements of the Hifiman Arya headphone

Fig. 19, which compares measurements of the Focal Clear taken with three different GRAS rigs, shows remarkable overlap from 60 to 1250 hertz. There will often be disagreement in the very lowest frequencies. This is due to the difficulties getting the ear pads to rest completely on the side of the measurement head surrounding the artificial ear with no air gaps. Equally, there are typically disagreements in the high frequencies above 2 kHz. Fig. 20 of the Hifiman Area — the first planar magnetic we've looked at — is a bit rough in the middle frequencies (I suspect unit variation), but overall quite consistent up to 3 kilohertz and again remarkably consistent past 4 kilohertz.

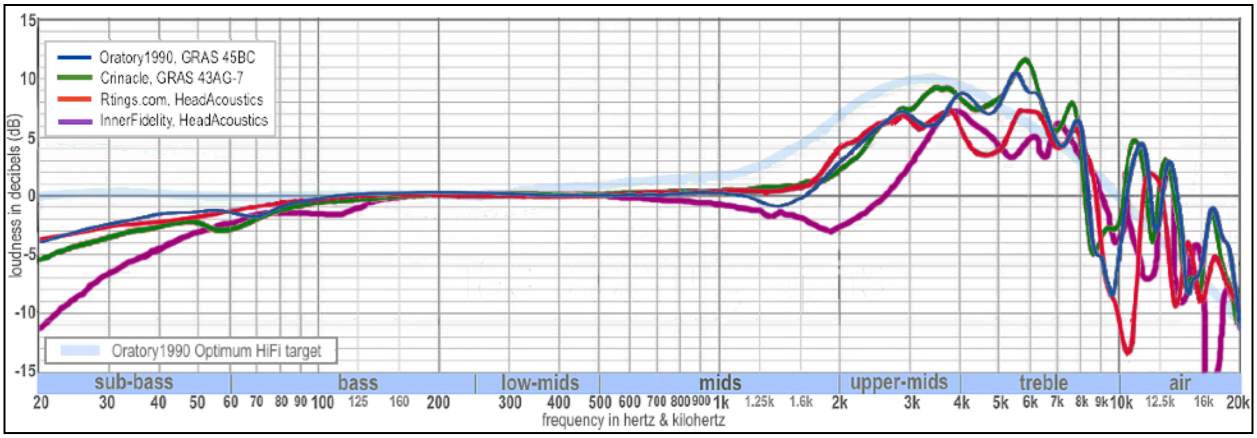


Fig. 21: four-way comparison of raw measurements of the Sennheiser HD 800S headphone

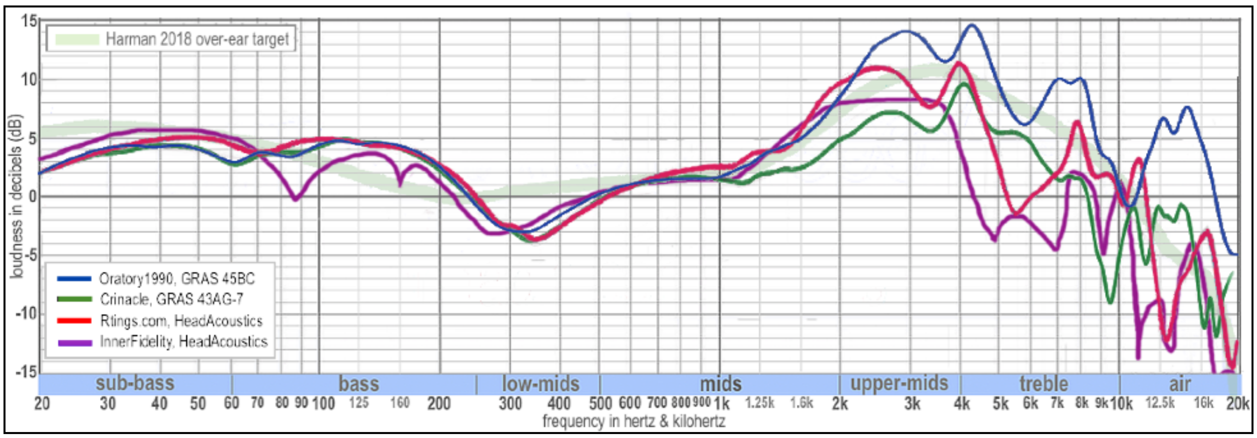


Fig. 22: four-way comparison of measurements of the Audio-Technica ATH-M50x

With Figs. 21 and 22 we're adding the two HeadAcoustics measurement rig sites into the mix. If these graphs are getting more and more confusing to the eye, that's pretty much the point.

In Fig. 21 we see the nice overlap in the middle as in Fig. 19. The two GRAS lines show the same so-so level of agreement we see above, while the two HeadAcoustics lines diverge more. The InnerFidelity line seems if it's from an entirely different headphone. But in Fig. 22 we're seeing differences *everywhere*. Not sure what to attribute all this M50x variance to, but fortunately Fig. 21 seems more typical of the kind of divergences we can expect between the measurements from these sites.

Another factor, beyond measuring equipment, is unit-to-unit product variation of the headphones themselves. Suppose you buy three units of exactly the same headphone that you find right beside each other on a store's shelves. Suppose you then send them to one of the review sites asking for measurements. Experience shows there would be measurable differences between the three units.

So when we look at Fig. 22, for example, we have no idea how much of the discrepancies between the measurement curves is due to the test equipment being used and how much is due to unit-to-unit differences between the individual M50x units that were measured. Here are the measurements for three different units of the Sennheiser HD 800S posted on InnerFidelity:

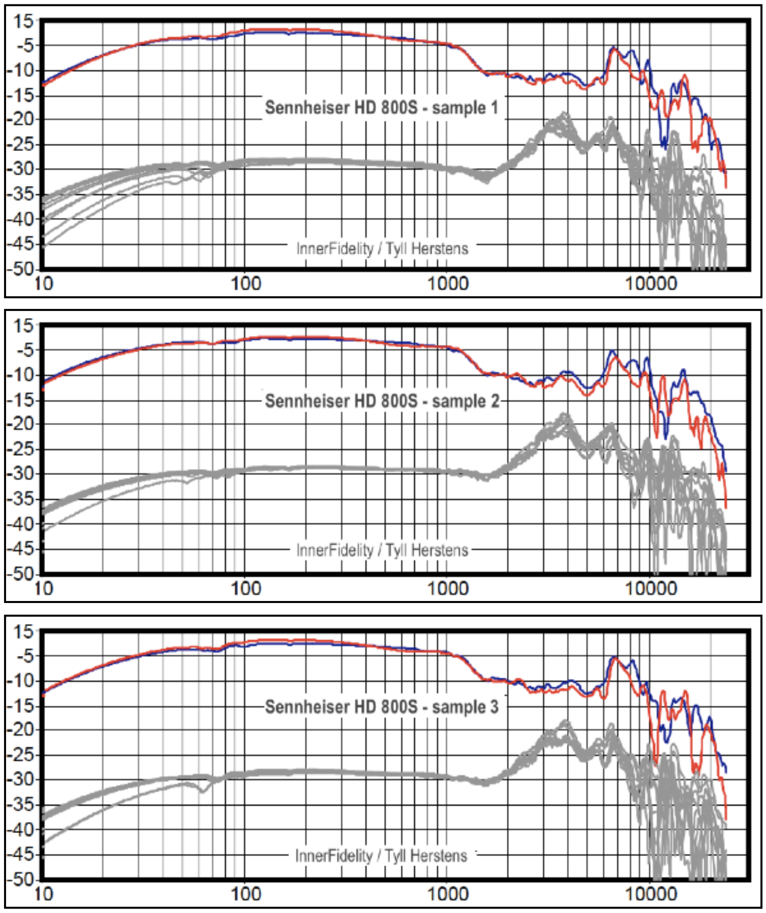


Fig. 23: three production units of the same HD 800S headphone model

As previously mentioned, the left red and blue lines show the average of the five measurement re-seatings (see below) from each ear cup, but "corrected" with a weighting intended to remove the bias of the measurement rig. The near-perfect overlap of the left and right driver measurements out to three kilohertz shows the superlative results Sennheiser was able to achieve for one of its flagship models. This carries over into the very minimal divergence from one unit to the next.

Yet another factor is what we call *silent revisions*. Manufacturers occasionally change internal components or assembly procedures over time in the production of a particular headphone model. A common scenario is for a manufacturer to experience a significant number of returns after releasing a new model headphone. The manufacturer will investigate what the failure was then fix the problem, if possible, in the production of that model going forward. (It's always wise to hold off for several months on purchasing an exciting but brand new product.)

Silent revisions, however, can occur at any point in a product's life cycle. Just one cause is a component supplier going out of business. Planar magnetic driver technology is still evolving as several firms continue to push the performance envelope with new materials and manufacturing techniques. Some of the more boutique of these companies make changes to existing models to incorporate new developments without changing the model designation. So any difference between Oratory1990 vs Crinacle vs Rtings, etc. measurements, for example, may be due to actual differences in the production run of the headphone model being tested. The on-going saga of the Hifiman Sundara as I write this in early 2021 with two significant revisions to the ear pads in the last two years to increase durability is a dramatic case in point.

Yet another factor — the ear pads on some headphones are made of materials with desirable acoustic properties but that compress and degrade significantly over time:

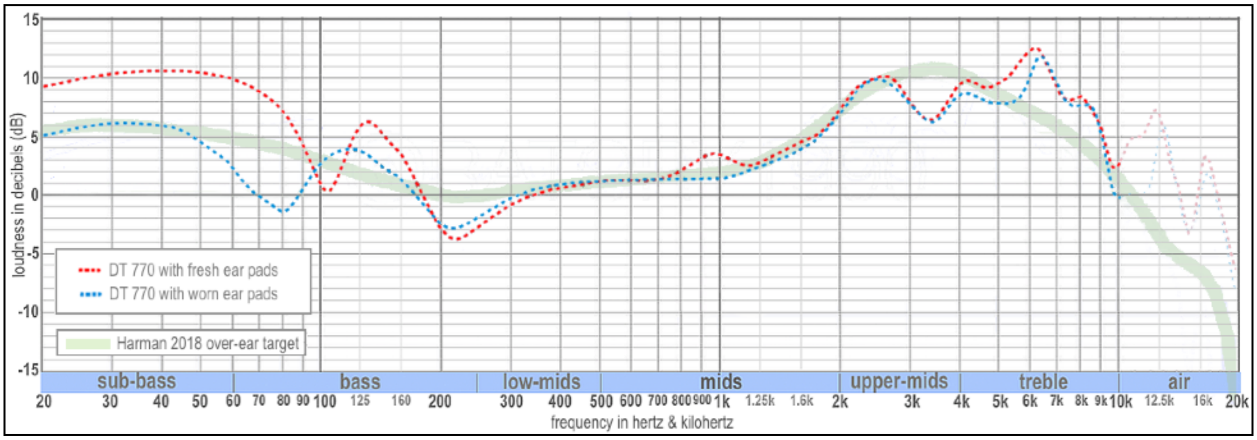


Fig. 24: effect of pad wear on the beyerdynamic DT 770 (Oratory1990 data)

Teasing out which factors are at play in the discrepancies between graphs from different sources of the same headphone borders on impossible. So again, when details are important all we can do is restrict comparisons to headphone measurements from the same source.

And finally there is a very large fudge factor that is beyond both the manufacturer's and the measurement technician's control. I mentioned above that any competent technician will measure a given over-ear headphone multiple times in slightly different positions that result from the inner cavity of an ear pad necessarily being large enough to fit the largest ears but with room to spare for the majority of ears. Add to that different head sizes typically cause headphones to sit with more or less clamp force. This compresses the ear pads to a greater or lesser degree changing the cavity size and shape, which in turn changes frequency response. Here is a typical spread in the high frequencies from an Oratory1990 graph posted to illustrate the concept:

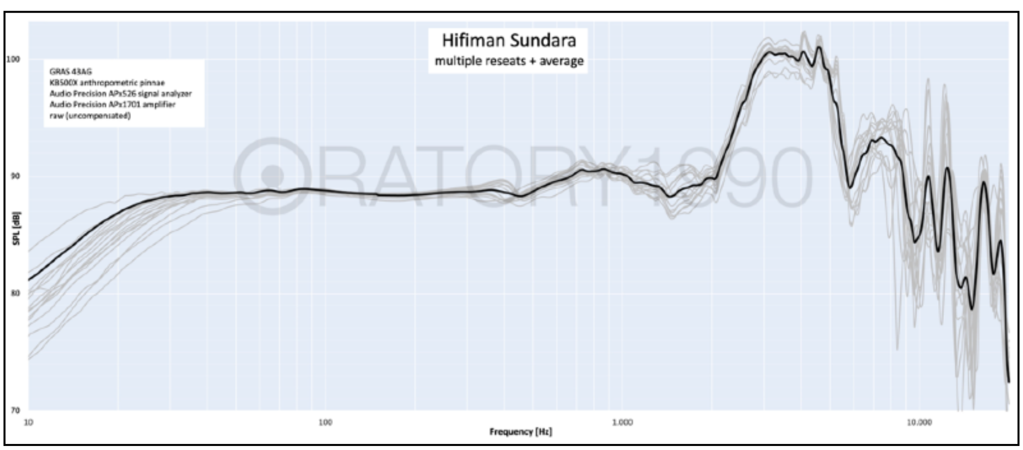


Fig. 25: Oratory1990 graph of the frequency response of a Hifiman Sundara showing multiple re-seats

The grey tangle is composed of at least 15 different measurement lines, each with the headphone moved slightly left, right, up or down around the ears of the measurement head. The larger spread in bass and treble versus mid range is typical. Many measurement sites, like Rtings and InnerFidelity show the measurement trial lines as well as the resulting average. While Oratory labels the black line in Fig. 25 as an average, its location near the top of the sub-bass suggests something else may be involved. Indeed, a nice thing about presenting the re-seating trials is in showing where a reduction of an unpleasant-sounding loudness or the increase in an unpleasant-sounding quietness might be achieved with an adjustment of the headphone on one's head.

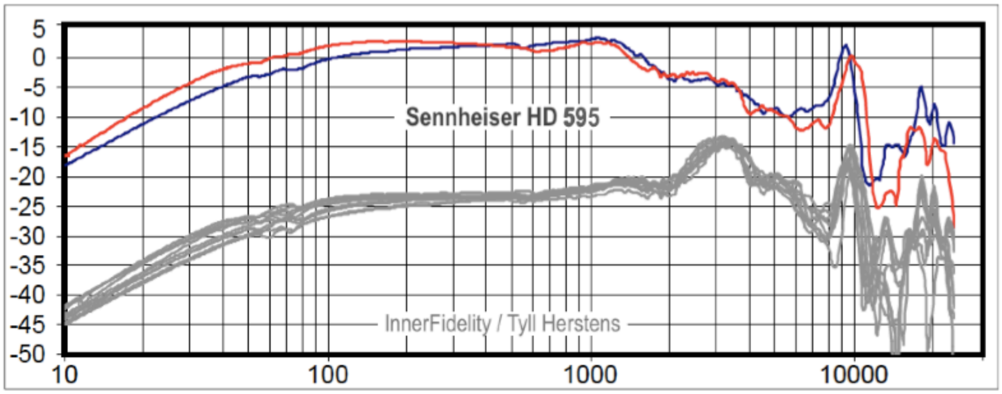


Fig. 26: InnerFidelity graph of the Sennheiser HD 595 showing multiple re-seats plus left and right ear responses

The heart of any headphone are the (typically) two drivers/transducers, one in each ear cup. As mentioned above, just as there is unit variation of frequency response from one unit to the next of the same headphone, there is also variation between the two drivers in a single headphone. Headphone manufacturers produce or order large numbers of the drivers for a given model. Then they measure and sort them to create pairs as closely matched as possible. But perfection is clearly not an option.

In Fig. 26 I also included the red and blue lines. The red line is an average of the left ear measurements and the blue, the right ear. The amount of difference between the two tends to vary from manufacturer to manufacturer. Typically, this is on the order of one or two decibels across the frequency range, like we see in Fig. 23, for the premium models of the well-established, large market share companies. But in other cases three or more decibel variance between units is not uncommon, as we see in the budget open-back HD 595 in Fig. 26.

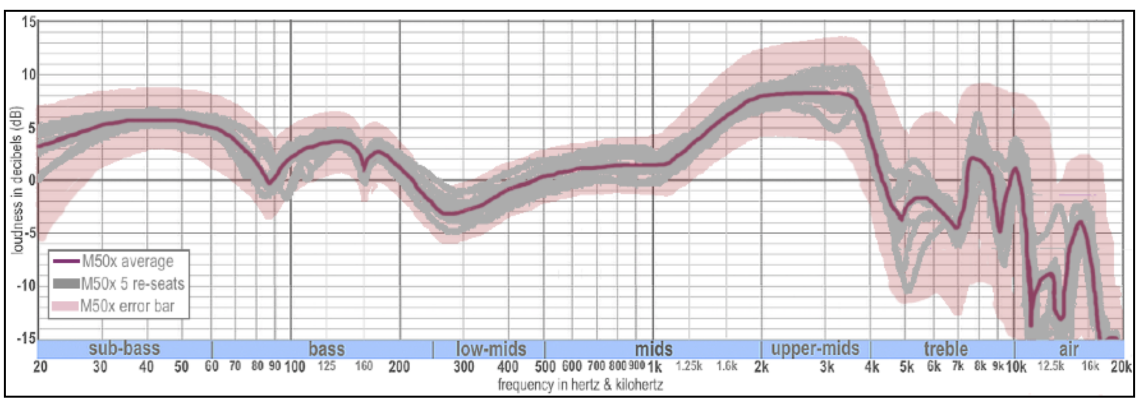


Fig. 27: M50x graph with re-seating trials and (fictitious) error bar

So — do good measurements agree? Clearly and resoundingly no. The graphs and data plots in science research papers include error bars to show visually how much variance or room for error there is in each measurement. The evidence presented in this section suggest huge error bars are missing from the neat, tidy, precise-looking graphs we see posted in great numbers on-line. When even a GRAS 45 and a GRAS 43, both fitted with the expensive anthropomorphic ear analogue option, fail to agree with each other — when unit variation and silent revisions on the manufacturer's end play equal or greater havoc — when the headphones give different responses simply due to play in positioning on the listener's head — caveat emptor is reigning in full force.

Are good measurements useful?

Despite all the above, good measurements are not useless. I would look at GRAS 45BC measurements done by a skilled technician like Oratory1990 as most likely coming closest to an accurate portrayal of the average-ear frequency response of a given headphone. But beyond that, quality measurement graphs still serve to answer questions like: “does this headphone have a reasonably accurate frequency response? Does this bass elevation on this headphone bleed well into the mid-range? Is the treble on this headphone likely to stab at my eardrums? Questions like these are the proverbial meat and potatoes of endless forum arguments and endless buying decision deliberations. Many of us maintain that even a tainted dose of objectivity is a useful antidote to the unfettered subjectivity that otherwise prevails.

A given measurement rig may not be completely accurate in delivering the correct frequency response for the hypothetical anatomically average human ear. But since few of us sport a pair of those average ears, a particular measurement rig may actually give a more realistic result for your hearing than a theoretically more correct rig does. One point of variance between sites is the sub-bass. But this is due to the intrinsic problem that ear cups can be seated in a fairly wide range of positions on an adult head. Presumably each person will tend to optimize positioning. From there, the range of frequencies from about 80 to 1200 hertz tends to be pretty consistent between the better measurement rigs. But higher frequencies start to diverge again, paralleling the wide variability in human ear anatomy.

A critical aspect of this are ear canal resonances. Every tube has a natural resonance frequency. For the ear canal, depending on its length, cross-section shape, friction, etc., this frequency is *on average* 2.5 kilohertz. But multiples of this frequency are also resonant:

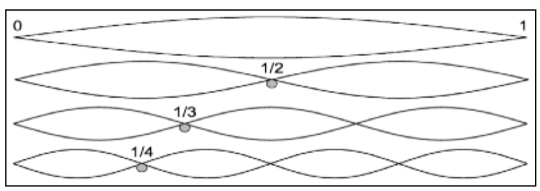


Fig. 27: first four vibrational modes

So that yields the series 2.5, 5, 7.5, 10, 12.5 and 15 kilohertz within the range of human hearing. But for someone whose ear canal has a resonant frequency of 2.7 kHz, the series becomes 2.7, 5.4, 8.1,10.8, 13.5 and 16.2 kilohertz. The upshot is each of these frequencies gets a signal boost curtesy of the ear canal. If your particular ear canals generate a signal boost at 8 kHz and the headphone you’re listening to has a loudness spike at 8 kilohertz, then whenever the music or speech you’re listening to peaks at 8 kilohertz you’ve got a problem. The straight tube ear canal of a HeadAcoustics rig may not match the hypothetical average ear canal — which includes both male and female ear measurements — but it may be a closer match to one or both of your own ear canals. The same basic idea applies to variance in outer ear shape and even to the boundary gain imparted by the human head and torso.

Unfortunately, as we’ve seen other variables, such as unit variation and ear cup seating, are likely to obscure any match between your ears and a particular measurement rig. Whether researching a new purchase or creating an EQ curve for a headphone you own, you cannot count on any given measurement being truly accurate to a particular unit of a given model of headphone at any specific frequency. But understanding how to weight all the variables we’ve discussed will take you a long way to bridging the gap.

✣ ✧ ✣ ✧ ✣ ✧ ✣

And that's it. You're now far more knowledgeable about headphone frequency response graphs than 90% of the Internet's self-appointed expert forum commentators. By the way, in this unit we only looked at measurement graphs for over-ear headphones. But all the concepts apply equally to the separate world of in-ear monitors (also known as earphones). The main difference is that a different set of target response curves are typically used for in-ears. Also, all the headphones we looked at, excepting the two Hifimans and the HEDDphone, use dynamic (cone) drivers. Again, all concepts apply to planar, electrostatic and, yes, even AMT driver headphones. But, especially with planars, the amount of unit variation, plus the frequency of silent revisions, makes it difficult to treat any individual unit's measurement as representative of a given model.

In this episode we looked at what the frequency response of headphones actually looks like when properly presented, why they sometimes don't and how much they can be trusted even when no trickiness is involved.

So now be sure to proceed on to the next exciting instalment in my must-read Headphone Essentials series: HE5: The whole flat/neutral/Harman headphone thing. In that episode we'll delve into what headphones *ought* to sound like but don't. We'll do this while exploring the mysterious world of headphone target response curves that we used but didn't explain in this unit.