

Miracle Solution?

What EQ can – and cannot – do

By Pat Brown

Almost every sound system has an equalizer. It can be as simple as a channel strip tone control or as sophisticated as a multi-band parametric.

Some view the use of equalization as an art form, while others see it as distinctly technical in application. The prevailing myth is that an equalizer can correct all of the shortcomings of a sound system. Of course this is nonsense, but used properly, equalizers can improve the sound quality and general performance of most sound systems.

Rather than covering every aspect of equalizers and their use, let's have a look at ways of achieving the best overall results in the shortest period

of time. The approach is technical, not artistic.

Let's work under the assumption that we have a means of measuring the magnitude of the frequency response of the direct field of the loudspeaker. Some of the mainstream tools for doing this include (SIA) SMAARTLive, (Morset) WinMLS, (Gold Line) TEF, (Meyer) SIM, (DRA Labs) MLSSA, (Liberty) Praxis and others.

The procedure often followed for equalizing a loudspeaker is to place the measurement microphone on-axis and adjust for the flattest frequency response. This involves cutting and boosting some filters on the equalizer.

Those that are opposed to the use of boost filters may choose to arrive at

the same resultant response by reducing (cutting) parts of the response to the lowest common denominator. This results in the same electrical curve, but without compromising headroom in the signal chain.

None of this is rocket science, and the process could be relegated to a computer algorithm. As useful as this exercise is in producing a flat on-axis response curve, it ignores what is going on at other vantage points around the loudspeaker and may actually reduce the overall sound quality from the system/room for many of the listeners.

A modification to this approach: considering the off-axis as well as the on-axis response (not a new idea but this may speed the process). The goal of the equalization process is to produce a better sounding system for all of the audience.

Yet a relatively small percentage of the audience sits in the on-axis position. It would therefore seem ill advised to consider only the axial position when equalizing a system. A possible solution is to average the response of a number of seating positions to arrive at the best "common denominator" curve for the equalizer. This is called a spatial average, and while useful, there are some major drawbacks, including:

- The measurement microphone is in a different acoustic environment each time you move it. This makes it difficult to isolate the direct field without a lot of setup work.
- Loudspeaker interactions can produce huge swings in the frequency response from seat-to-seat. A spatial



Figure 1: Axial frequency response of a multi-way loudspeaker, with the dip in response at 2 kHz due to phase cancellation between multiple drivers.

average can't correct this. This means that equalization should initially be conducted on one loudspeaker at a time.

- While the symptoms of acoustic problems can be observed with this method (i.e. uneven coverage) the cause cannot.

- It's not practical or possible to measure at all positions around the loudspeaker, so the equalization curve is influenced by relatively few measurements.

Because any adjustments with an

equalizer affect the total radiated energy, it is wise to give consideration to all of the radiated energy. The spatial average is not a bad idea, it's just hard to implement.

DIFFERENT WAY TO SAME

Another way to consider off-axis listener positions is to determine the base equalization curve for the loudspeaker by observing its three-dimensional radiation balloon. A properly gathered balloon will reveal the ane-

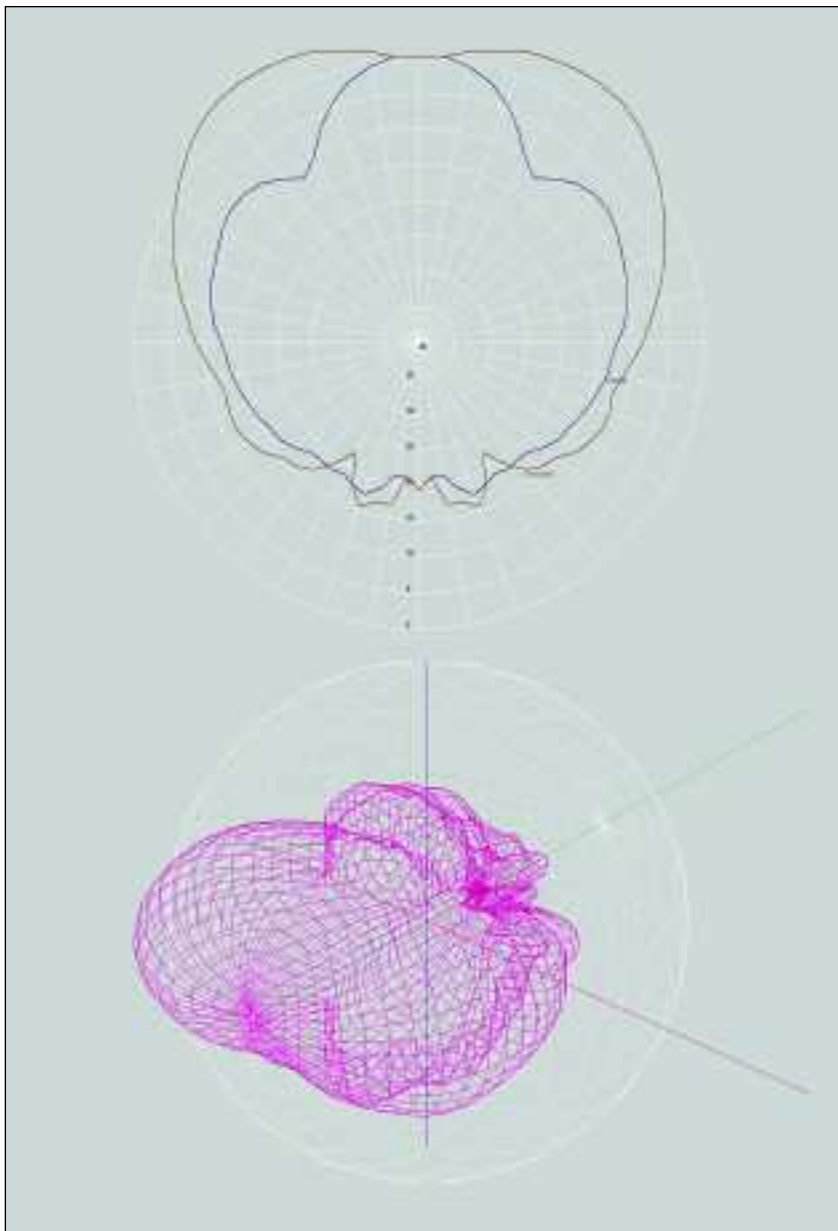


Figure 2 and 3: The polars (above) and entire radiation balloon at 2 kHz. Even though they cancel on-axis, the devices come into phase at two off-axis positions.

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choic response of the loudspeaker at all listener angles.

Because the direct field of a loudspeaker is considered to be largely independent of the acoustic environment (at least at short wavelengths), direct field equalization based on balloon data has a strong theoretical basis.

Figure 1 (page 68) shows the axial frequency response of a multi-way loudspeaker. The dip in response at 2 kHz is due to phase cancellation between multiple drivers in the box. A

boost filter at this frequency center will restore the axial response to flat. Observation of the polars and the entire radiation balloon at 2 kHz (**Figure 2 and 3**, page 69) shows that even though they cancel on-axis, the devices come into phase at two off-axis positions. At these angles there is most likely a significant peak in the response for many of the audience members.

The “correction” made to the on-axis response will likely worsen the

off-axis response where a greater number of listeners are located. Worse case is that one of the off-axis energy lobes covers a microphone position, so a boost filter will likely worsen the gain-before-feedback.

Devices that have a destructive phase offset at one listener position are likely to have an in-phase relationship at another. The on-axis notch might better be addressed by the use of precision signal delay between the elements to bring them into phase rather than feed them more energy.

WHAT THEY DO

In general, the use of equalization will inflate or deflate the radiation balloon at a specified octave band. The same effect occurs at all angles around the device.

But what is often needed is a re-shaping of the balloon. This can be accomplished by using multiple elements and varying their physical spacing and relative delay. This is the heart and soul of loudspeaker design. Boost and dip filters applied based on the axial response only have a minimal affect on the balloon shape for those frequencies.

A good loudspeaker design will direct the radiation lobes toward the audience. For frequency bands where this is not happening due to phase interactions, precision signal delay can be used to steer the lobes to the desired position. It's counterproductive to just pump more energy into the loudspeaker and increase the level for all listeners, which is exactly what an equalizer does.

It should be noted that psychoacoustics also plays a role in this. Peaks in a frequency response are much more audible (and bothersome) to humans than dips in the response. We're more aware of “too much” than “too little.” A safe approach to equalization that embodies the theories described here is to avoid the use of boost filters when calibrating a sound system since it's better to have “too little” than to have “too much.”

By observing the axial response for equalization, and using cut-only filters to smooth the resonant peaks, acceptable results can likely be attained for most listeners, because off-axis lobes

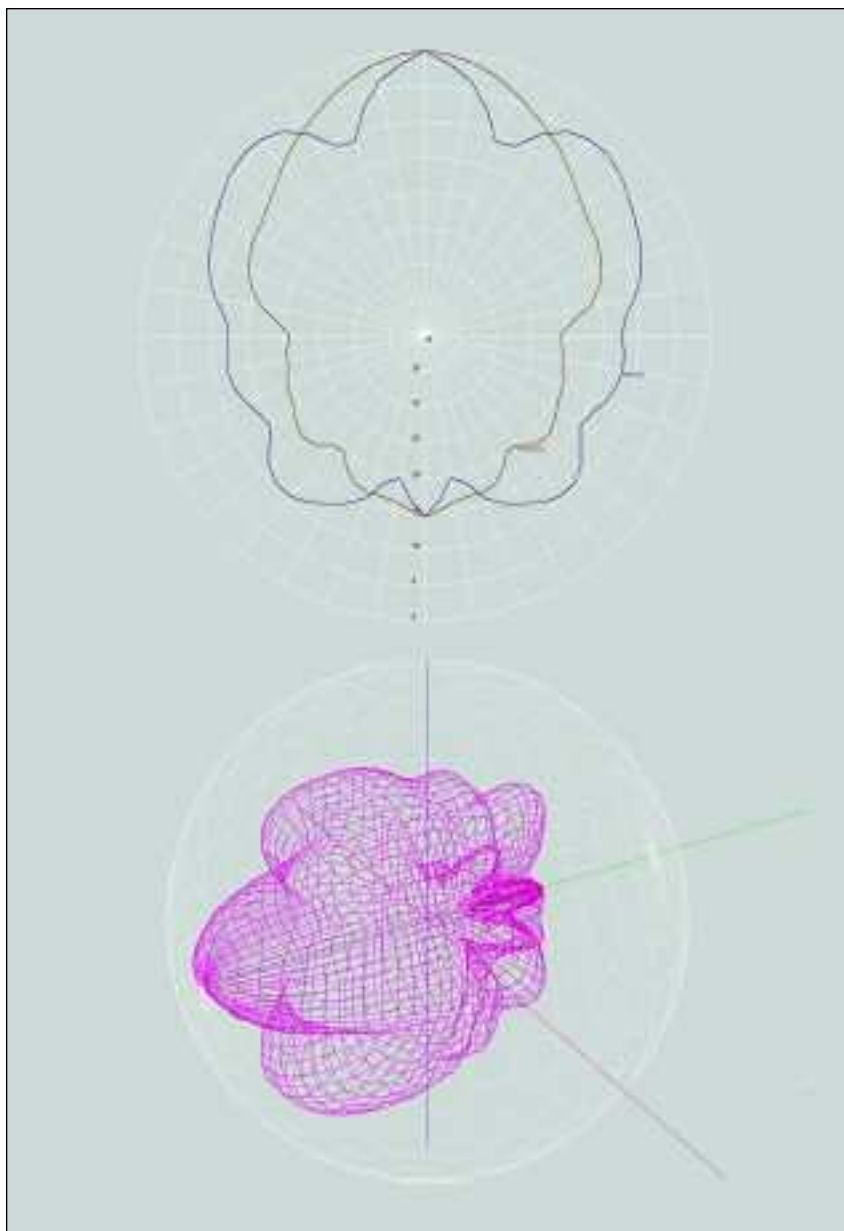


Figure 4 and 5: If the microphone were placed slightly off-axis when equalizing this loudspeaker, an attempt to achieve a flat response will likely overpower listeners at other angles.

will not be “inflated” by the process. The balloon data of a loudspeaker can reveal what will happen off-axis if a boost filter is implemented to smooth the on-axis response.

GETTING THE BALLOONS

The good news is that much of the work has already been done for you. It is not practical or even possible for end users to measure loudspeaker directivity balloons. The burden is on the manufacturer to provide this data.

Data balloons are available from many manufacturers in the data that they distribute for acoustic modeling programs. Some popular applications include (ADA Ahnert, Renkus-Heinz) EASE, (CATT) CATT-A, (Integral Acoustics) LARA, and (IFBSoft, Community) Ulysses. A platform-independent data format that is growing in popularity is the Common Loudspeaker File format (CLF).

CLF has an advantage in that other specifications are included besides balloons and a free data viewer gives access to the data without the purchase of a modeling program (www.clfgroup.org).

Here is an orderly approach to using information from balloons plots to optimize the equalization process:

1) Measure the magnitude of the frequency response for the on-axis listener position. It is very important to use a mic placement and/or time win-

dow to exclude the room reflections (especially the floor bounce). Also the mic should be in the far field of the loudspeaker (at least 3x its longest dimension away).

2) Decide what correction is needed to flatten the direct field. Start with frequency bands that have too much energy and reduce them with the equalizer.

3) Next consider frequency bands where there is too little energy. Don't boost them, but look at the radiation balloons and see if any off-axis lobes exist that are higher in level than the on-axis response. If so (and it is likely to be so) do NOT boost this region with the equalizer.

4) If the radiation balloon is well-behaved off-axis then boost with care. This will usually only be true at the frequency extremes, where only a single device is producing sound and the band-limits of the transducer are being approached. An exception could be the compensation need by constant directivity horns, but again, a look at the balloon data will tell if the high frequency roll-off is happening at other listener angles.

5) Multiple device interactions should not be “corrected” with equalization. These will be clearly observable in the polars and radiation balloons (**Figure 4 and 5**, previous page). If the microphone were placed slightly off-axis when equalizing this loudspeaker, an attempt to achieve a

flat response will likely overpower listeners at other angles.

INFLATE OR DEFLATE

It's important to differentiate between inflating a radiation balloon and reshaping it. Equalizers inflate (or deflate), whereas delay or physical movement between loudspeaker elements reshapes the balloon.

Many “corrections” that are made by looking only at the axial response cause worse problems than they are solving. Manufacturer-supplied radiation balloon data is the most accurate and simplest way to look at the off-axis response of a loudspeaker.

It's plausible that the complete equalization of the direct field can be determined from the axial frequency response and the spherical balloons. The remaining room-dependent equalization chores can be left to the installer or commissioner of the system. This can include compensation for boundary loading, device coupling, etc.

The possibility also exists based on the above for a manufacturer to provide an appropriate equalization curve in the form of a simple magnitude vs. frequency plot or as a setting that can be imported into popular digital signal processors. ■

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