Technical Paper
Number 108

When Was The Last Time You Heard A Perfect Room?

Home Theater Acoustical Problems and Equalization Solutions

by

Frederick J. Ampel

Frederick J. Ampel is now active in or has been active in almost every aspect of the audio/video industry. He has an MS in Television Sciences with a BA in Music. He is the principal Editorial Consultant with Systems Contractor News and past editor of Sound and Video Contractor magazine. His career includes live sound reinforcement, broadcast production, recording studio design, and home theater system design, installation and equipment development.

AudioControl®

Price $1.00

22410 70th Avenue West, Mountlake Terrace, WA 98043 (425) 775-8461

When Was The Last Time You Heard A Perfect Room?

Home Theater Acoustical Problems and Equalization Solutions

System designers, installers, and consultants face a constant series of problems in delivering the kind of Home Theater performance clients have a right to expect for their money. Each and every room is unique, and each one presents a different blend of physical, and electrical limitations that can make even the most expensive loudspeaker system function well below its potential.

One of the most overlooked technologies for correcting, enhancing, and polishing the performance of loudspeaker systems used in multi-channel and distributed whole house audio applications is equalization.

No, we are not talking about the ubiquitous, and essentially useless “tone controls” provided on almost every preamplifier/receiver, or similar component. While having some application for the end users to adjust overall system tonality, these limited capability circuits simply cannot provide a sufficient range of control to modify the spectral content of the loudspeaker information presented to the room, and ultimately to the listener(s).

Some Recent Research

Before we delve into the applications and art of equalization it is crucial to understand several points.

First, no loudspeaker system operates in a spatial vacuum. In fact, the loudspeaker/room combination has far more to do with the perceived sonic impression of any system than do either of the individual pieces. Extensive, decade long studies conducted by the National Research Council Of Canada, and the Canadian Audio Research Corporation unequivocally show that “ both the loudspeaker and room acoustically interact in ways that (significantly) alter the timbral and spectral aspects of the reproduced (recorded) event. Unless these errors are removed prior to the listening process, objective evaluation of performance can no longer be assured.” (See references at end of this paper.)

Secondly, this same comprehensive research project determined that “ for loudspeakers of conventional design, a flat on-axis frequency response is a reasonable target.”

Third, based on a parallel project conducted by the same research group, it was decisively shown that “without question loudspeaker performance and thus listener preference are singularly dependent on their placement within the listening room.”

This information has direct bearing on every installation! Why?

Rarely is it possible to place the loudspeaker systems precisely where they will perform best. Additionally, the room's acoustic signature is determined by factors beyond anyone's control. As if that were not enough, the size and relative performance of the main and surround systems are often unavoidably compromised, leading to unequal capabilities and frequency response variations that may not be helpful. (The best speakers will not fit either physically or decoratively.)

OK - so there is a problem, or more correctly a series of problems.

What can we do about it?

The Processes Used by Professionals

We can apply the same techniques and technology used by professional recording, broadcast, post production, cinema sound, and mastering engineers and facilities for the past four decades - precision equalization.

Every single professional audio production/post production room uses as an integral part of its audio playback chain, a carefully chosen selection of equalization devices to guarantee that the spectral response at the listening position is as accurate, spectrally broadband, and as smooth as technically possible. This is not an option for these facilities, because the decisions they make regarding the relative levels, timbral balance, and blending of the multiplicity of various elements that go into today's soundtracks, CDs, television programming and other source material must be correct. This is how they make their living, and they cannot afford inaccuracies that cause problems at the consumer end of the chain.

In these applications, the signal fed to the loudspeaker systems is modified using a combination of 1/3rd octave or 1/6th octave band, and parametric filters. Each of these devices serves a specific purpose in the overall process of insuring that what gets into the room is correct. By correct we mean that the signal that is delivered from the loudspeaker to the room, and the subsequent interaction between that signal and the room produces the optimal spectral balance and response curve for the listening position.

In many cases this means *removing* information from the incoming signal to prevent problems, or re-balancing the overall spectral content of the incoming drive signal for each loudspeaker or loudspeaker position, to allow the affects of the loudspeakers themselves and the loudspeaker/room combination to bring about the desired end result.

The Nature of Sound

In order to understand the process more thoroughly, let's look at a few graphic representations of the audio signals that we will have to deal with.

Figure 1 on the next page shows the frequency range for a wide variety of instrumental sources. Regardless of the type of program material your clients listen to, you will encounter many if not all of these sources on recordings and broadcasts. Having a good basic comprehension of what an instrument can generate will help in determining how to approach the use of equalization to correct the signal to deliver a realistic, and accurate portrayal of the source.

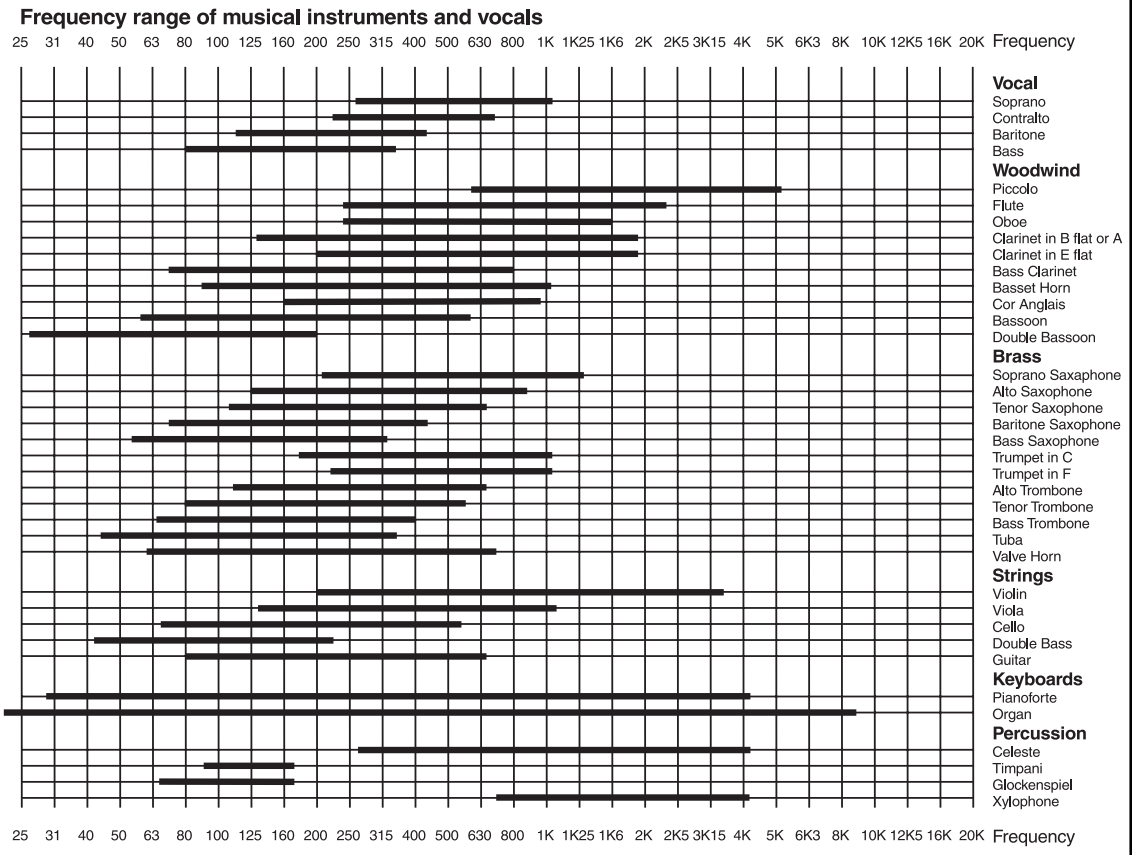


Figure 1

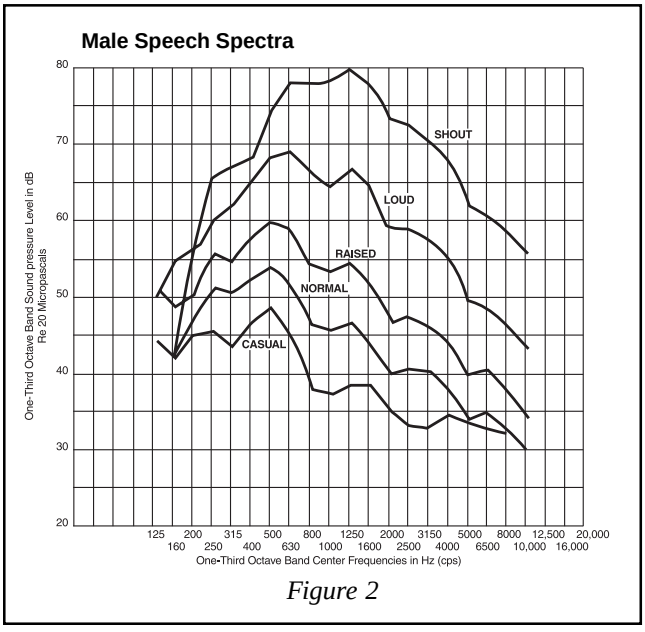


Figure 2

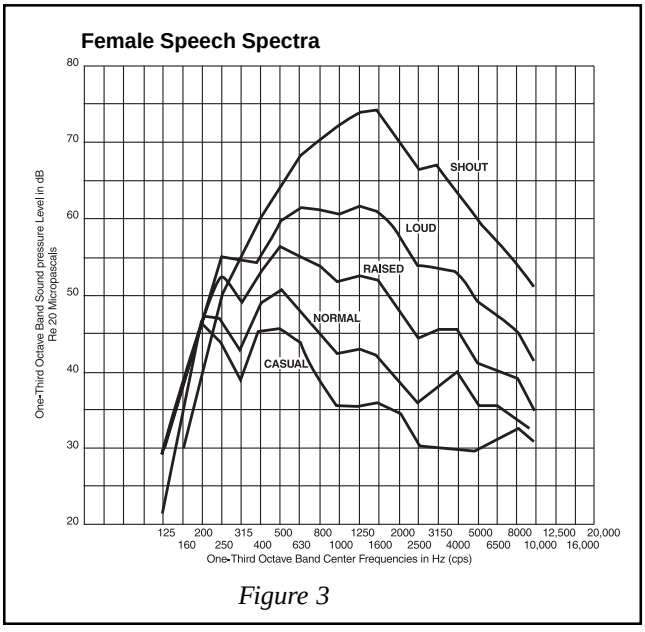


Figure 3

Figures 2 and 3 show the male and female speech spectra for various 'output' levels. Examining these charts will also help in building a knowledge base of the frequency ranges being covered and how to use tools to provide improved intelligibility and naturalness.

Effects of Equalization on Voice Reproduction

1/3 Octave center frequency (HZ)	Effect on voice
40, 50, 63, 80, 100, 125 160, 200, 250 315, 400, 500	Sense of power in some outstanding bass singers. Voice fundamentals. Important for voice quality.
630, 800, 1K	Important for voice naturalness. Too much boost in the 315 to 1K range produces a telephone-like quality.
1.25 to4K 5, 6.3, 8K	Vocal fricatives - accentuation of vocals. Important to speech intelligibility. Too much boost between 2 and 4KHz can mask certain speech sounds e.g. 'm', 'b' and 'v' can become indistinguishable. Too much boost anywhere between 1 and 4KHz can produce 'listening fatigue'. Vocals can be highlighted by slightly boosting the vocal at 3KHz and at the same time slightly dipping the instruments at the same frequency. Accentuation of voice.
	The range from 1.25 to 8K governs the clarity of voice.
10, 12.5, 16K	Too much boost causes sibilance.

Figure 4

Effects of Equalization on Music Reproduction

1/3 Octave center frequency (HZ)	Effect on Music
31, 40, 50, 63	Fundamentals of bass drum, tuba, double bass and organ. These frequencies give music a sense of power. If over emphasized they make the music 'muddy'. The 50 or 60Hz band is also used to reject ac. mains hum.
80, 100, 125	Fundamentals of lower tympani. Too much boost produces excessive 'boom'. The 100 or 125Hz is also used for hum rejection.
160, 200, 250	Drum and lower bass. Too much boost produces excessive 'boom'. Also useful for 3rd harmonic mains hum rejection.
315, 400, 500	Fundamentals of strings and percussion.
630, 800, 1K	Fundamentals and harmonics of strings, keyboards and percussion. Boosting the 600 - 1KHz range can make instruments sound hornlike.
1.25 to4K	Drums, guitar, accentuation of vocals, strings and brass. Too much boost in the 1K to 2KHz range can make instruments sound tinny. Too much boost anywhere between 1K to 4KHz can produce 'listening fatigue'.
5, 6.3, 8K	Accentuation of percussion, cymbals and snare drum. Reduction at 5KHz makes overall sound more distant and transparent. Reduction of tape hiss and system noise. The 1.25 to 8K governs clarity and definition.
10, 12.5, 16K	Cymbals and overall brightness. Too much boost causes sibilance. Reduction of tape hiss and system noise.

Figure 5

Figures 4 and 5 explain the effects of equalization on voice reproduction and music reproduction.

These two charts should become an integral part of everyone's "audio tool kit" because they enable understanding of exactly how each equalizer control affects the signals being processed.

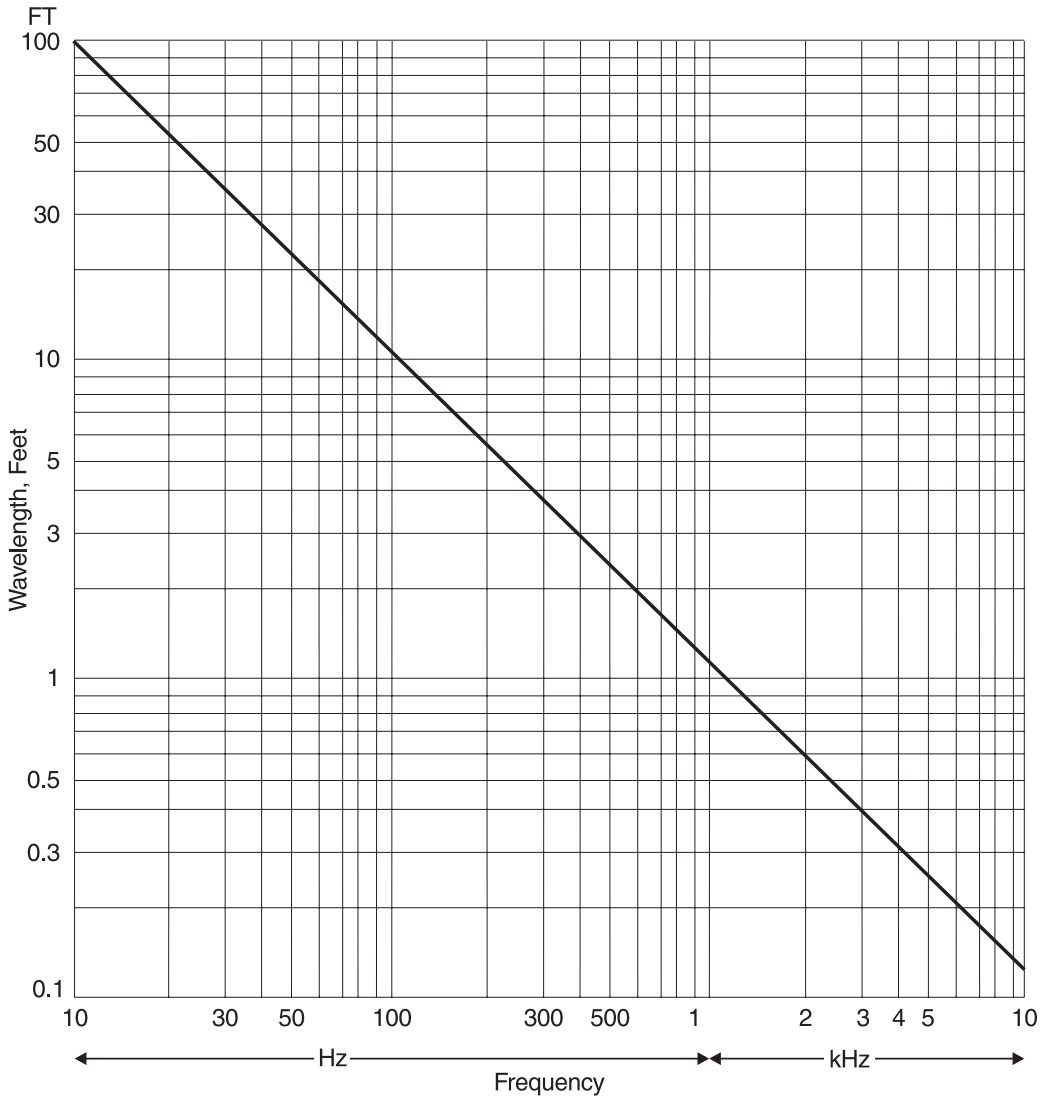


Figure 6

Figure 6 shows the wavelength of a sound versus its frequency. By knowing the wavelength, we can quickly calculate what standing wave and reflection problems are likely to occur. With that knowledge, choosing the right approach to equalization and other methods of acoustic correction for every room is easy.

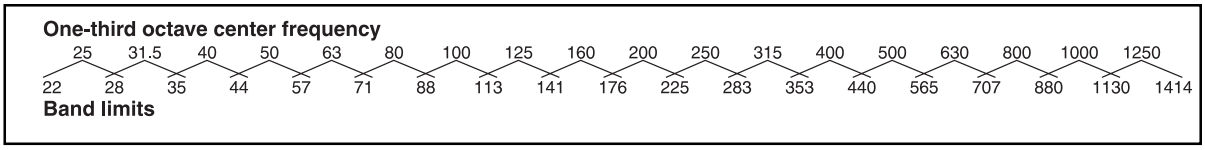


Figure 7
Showing how 1/3rd octave equalizer bands cover a range of frequencies.

Dramatically Improve the Performance

Armed with this data, and with a little practice you can easily and effectively use the various equalization products available to often dramatically improve the performance of a system, in the space in which it will have to operate.

Let's look at examples of the way in which equalization can be used to produce better sounding audio systems.

Before we begin, here are three critical points to remember:

1. It is always, repeat always, better to cut something out with equalization than add something in. Adding energy to a particular band drives the power amplifiers and loudspeaker harder, and pushes the whole system closer to distortion of all kinds, while reducing available headroom everywhere. Cutting takes troublesome energy out of the system.
2. In multi-channel systems using a decoder, always insert equalization at the output side of the decoder, before the power amplifiers. Since all equalizers produce some phase shift (which helps counteract the phase shifts caused by the room acoustics), inserting these devices in front of the decoder can alter the internal phase relationships on which all Dolby-type decoders depend for their steering cues.
3. Although you may be tempted to equalize by ear, acquire a good quality real time 1/3 octave spectrum analyzer system and learn how to use it (they don't have to cost $5,000 - a lot less in fact). Position your measurement microphone at the center of the listening position, and **after each step check several other points in the general area to insure you did not measure in an acoustically unusual position.**

It is a good idea to practice this measurement technique in the demo room or at home and get comfortable with the system. Remember, the instrument can only tell you what it sees, it does not make judgments. It can tell you things you cannot correct (1dB variations for example), and more importantly, things you and your clients won't ever hear with real program material as compared to the pink noise test signal. (If you already own one you're one step ahead of everyone else!)

Some Specific Solutions

EXAMPLE #1: *The small center channel:*

Many systems require that the center channel speaker be of a smaller size than the left and right speakers, and be located either above or below the picture.

Many of these center channel units are dual cone driver (DiApolito array) designs, and therefore have some response variations due to the multiple driver configuration. Using the speech spectra data provided (since 90+% of all dialog [speech] in film comes from this one speaker) you can apply small amounts of equalization to first balance the overall frequency range of interest. Remember that poor dialog intelligibility is perhaps the single biggest complaint people have about their home cinema systems. Work towards insuring that the signal present to this speaker. . .

A: falls within its specified operating range

B: has a measured response with no significant dips or peaks on axis (theoretically the center of the listening/viewing position)

C: sounds natural and unforced on a variety of sources.

In most cases a few dB of correction in the right places along the speech band can do absolute wonders for the irregularities present in many of the small, dual-cone driver, center channel systems currently on the market. The listeners will be much happier.

Obviously this speaker must also handle a wide range of other source material (music, explosions, etc.) so judicious use of corrective equalization is a wise move. You can always add in a bit more after completing the whole process, if warranted. Remember our previous point about the importance of cutting down peaks in the response.

EXAMPLE #2: *Splicing the subwoofer into the system:*

Another major problem area is smoothing out the response at the crossover point to the subwoofer(s).

This is not just a level question. Because several cone drivers are all reproducing some amount of the low bass signals in this region, significant response bumps and other variations are quite common.

By carefully shaping the input signal to both the main and subwoofer devices (and the surrounds and their subwoofer if this applies), you can often eliminate most of this unwanted information. You can also improve the overall bass response of the whole system, as well as delivering a more defined, crisp bass impact, due the lack of multiple arrivals, and additive frequency response variations caused by room loading.

EXAMPLE #3: *The high frequency/mid frequency question:*

Getting enough of each of these bands without too much is a delicate problem. Many smaller speakers have more than one driver operating across a fairly shallow crossover region leading to serious frequency response bumps as the signal moves from speaker to speaker or the listener changes position in the room.

By equalizing for flat on-axis response, in the room, at the listening position, you can drastically reduce the problem, and provide a more musical, natural sounding system for any application, in any remotely reasonable room. Happier listeners, again, will be the result.

EXAMPLE #4: *The "I've got some speakers already" problem:*

Matching various combinations of loudspeaker from several manufacturers or even within one company's range of products can be a trying experience. This is where equalization can save you from Excedrin headaches number 100 to and including 200.

First, you need to decide approximately what you want the overall system to look like on the real time spectrum analyzer, then determine what you really have in the space by measuring each speaker, as well as the whole system.

With that data you can then correct each speaker, and then if needed shape the total response to remove a significant amount of the box to box variations.

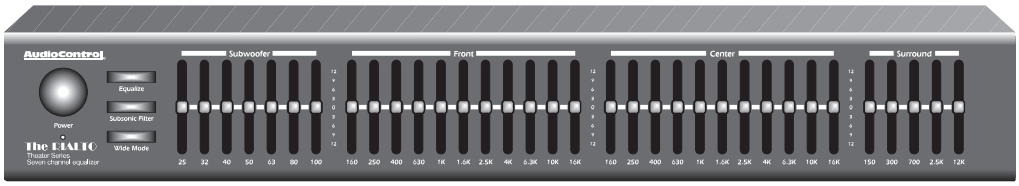
A Blatant Plug for AudioControl Products

So - if you made it this far you must be interested in exactly how to get your hands on the right tools and the right information.

It probably does not come as much of a surprise then, that the people at AudioControl have not only all the tools, but the test instrumentation as well. They have been exclusively specializing in this kind of thing since 1977 and have buckets of awards, patents and even products at work in The White House.

More importantly they would be delighted to sit down with you and show you what precision sound shaping tools can do, and how a small investment can make a big difference in listener satisfaction.

Remember, equalization is not a bad thing. In fact it is the one thing that almost every system you plan, and every one you have already installed, can benefit from. The people who produce the source material use equalization every day and know its importance. That's why they spend so much time and money 'tuning' their work spaces to deliver precise and accurate playback.



The Rialto

With unique products like The Rialto, seven channel equalization system, you and your customers can benefit from the same kind of sonic exactness. For about the cost of a mid-level VCR, you can install enough equalization to make a real difference in the performance of even a modest system.

At the end of the day, great pictures and poor sound equal no fun. Stunningly realistic sound and great pictures produce showcase systems and make for real, goosebumps-type enjoyment.

References

1. F.E. Toole, "Listening Tests-Turning Opinion into Fact," *J. Audio Eng. Soc.,* Vol. 30, No. 6., pp. 431-445 (June 1982)

2. F.E. Toole, "Subjective Measurements of Loudspeaker Sound Quality and Listener Performance," *J. Audio Eng. Soc.*, Vol 33, No.1/2. pp. 2-32, (Jan/Feb. 1985)

3. S. E. Olive, P.L. Schuck, S.L. Sally, and M.E. Bonneville, "The Effects of Loudspeaker Placement On Listeners Preference Ratings," presented at the 93rd Convention of the Audio Engineering Society, San Francisco, California, *J. Audio Eng. Soc.*, (Abstracts), Vol. 40, No. 12, p. 1039 (1992 Dec.), preprint 3352.

4. H. Staffeldt, "Differences in the perceived quality of loudspeaker sound reproduction caused by loudspeaker-room-listener interactions," presented at the 90th Convention of the Audio Engineering Society, Paris, *J. Audio Eng. Soc., (Abstracts),* Vol. 39, No. 5, p. 385 (1991 May), preprint 3046.

AudioControl®

22410 70th Avenue West, Mountlake Terrace, WA 98043 (425) 775-8461