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TAS ROUNDTABLE

# Room Acoustics: Audio's Final Frontier

Robert Harley moderates a discussion on room acoustics, equalization, and DSP-based room correction with TAS Senior Writer Robert E. Greene, Peter Lyngdorf of TacT Audio, and Art Noxon of Acoustic Sciences Corporation.

Robert Harley: I think everyone would agree that room acoustics dramatically affect the quality of reproduced sound. Given how important room acoustics are to sound quality, why have acoustics been generally overlooked by audiophiles, when they'll worry about things like the purity of the rhodium plating on binding posts?

Art Noxon: Air is free. Sound is free. Once generated, sound is free—from the speaker to your ears. You can't tax it or insure it. It's taken for granted, and there are no bells and whistles, and you can't plug it into the wall like you can a piece of equipment.

RH: You seem to be saying that because air moving in a room is intangible, it's overlooked.

AN: Absolutely. It's something that's taken for granted and it's assumed everything is fine, unless you stop to think about it. Or if you've got great components that don't sound great and you've exhausted all other options, then you may then consider that the room is at fault.

Robert E. Greene: I think another factor is that people don't realize how badly the room is behaving. They buy all the nice equipment, set it up, and start to listen. They hear some problems, especially in the lower frequencies, say, below 500Hz where the room really begins to have a dramatic effect, but they assume that's okay. I've had the experience over and over of going to someone's house with some measuring equipment and showing them that there's a giant hole at 200Hz and a big boom at 80Hz, and they're shocked. They've just been assuming that was what the recordings sounded like.

RH: They don't have a reference.

REG: They don't know that the distorted tonal balance—mainly too much bass—isn't in the recordings. I think it's one reason why audiophiles are obsessed with female vocals. It's because they know what the human voice sounds like in that range. That range is not terribly affected by the room.

AN: One of the easiest ways to hear the room's effect is to compare the sound of speakers in a room with a good set of headphones. Just play anything over headphones and listen to the musical clarity. Forget about imaging. Just listen to the musicality of what you're hearing over quality headphones. That's an easy, cheap way to get in contact with the phenomenon we're talking about.

RH: Peter, you have extensive experience with demonstrating DSP room-correction systems, showing people at hi-fi shows what music can sound like with the room-effects removed.

Peter Lyngdorf: I certainly have, and I've set up in a huge number of rooms over the years. The fact of the matter is that below roughly 300 or 400Hz, the room is the overwhelming factor in reproduced sound, and below 300Hz is where you have about 90 percent of the energy in an average piece of music. Below middle C on a piano, the sound is totally controlled by the room.

Most of the tonality of music is destroyed by an average room, and it is not only the tonality but the delays. Every time you have a resonance in the room, you also have a delay, which means that every time you extend the frequency response downwards with larger speakers, you will hit lower and lower resonances. Every one of those resonances is accompanied by a delay. If you have a resonance at 30Hz of 10dB, you are actually accumulating ten times the energy at that frequency, which means that the average delay at 30Hz then would be about 0.6 seconds. Consequently, the energy at that frequency comes almost at the next beat of the music.

So we have two issues: one is the tonality, the other is the timing.

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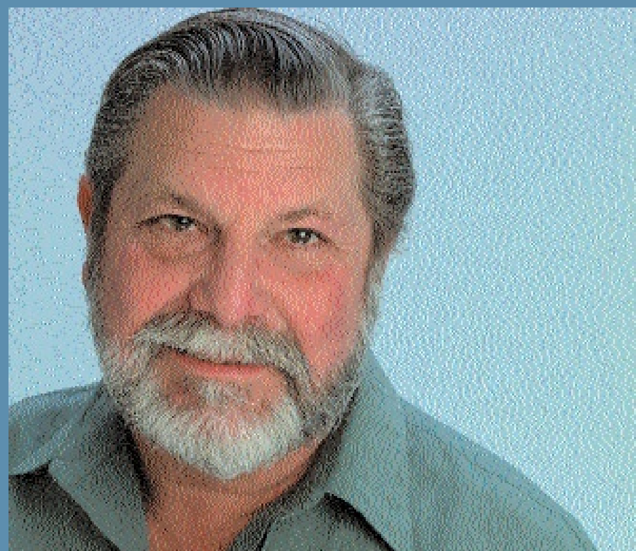
And timing is totally out the window if you do not have your room/speaker interface under control, and I believe that's one of the reasons that most musicians seriously hate hi-fi. The music is so totally out of beat that they can't stand it. And the bigger the speaker and the more powerful the system, the more they hate it.

Another thing which is quite interesting and actually quite funny is that a lot of manufacturers are consistently saying that their equipment needs to break in for two weeks or three weeks or four weeks, and I believe that is almost entirely nonsense, because very few products change dramatically over a few weeks. I think what they wait for is that the customer runs through all of his CDs one more time and finds another two or three tracks that sound pretty good in his room.



If we have no acoustic treatments in the room and we have a DSP processor,what happened to the articulation in the room? We're still injecting energy into the room.You still have reverberation time.You still have the lack of intelligibility that you had before.
—Art Noxon

RH: On the face of it, equalizers appear to be a tempting solution to fixing these problems, but audiophiles have abandoned them. Is equalization fundamentally flawed, or has the problem been in the execution of the products?

REG: Everybody in the consumer world has got it in his head that equalization adds phase shift, but, of course, it's really just the other way around. If you equalize the resonances out of a room, the correct timing is restored. The resonances themselves are generating phase shift. The resonances are technically known as "minimum phase." When you take away the resonance with equalization, the timing—the phase—also corrects itself.

AN: Equalization has disappeared from high-end audio. All the image-distorting widgets, which include equalizers, were taken out of high-end systems, just about the same time that the [Dahlquist] DQ-10 appeared and speaker designers realized that they had to get their speakers phase-aligned. I'm surprised to see equalization back in high-end audio—if it is back at all.

REG: I don't actually agree with that, at least in the bass. I think the phase shifts in the bass are generated by the room and eliminated by the EQ.

PL: Well, my view is that equalizers work, but it's important to have a good room to start with. So I don't think we are in total disagreement with Art. It's just that at the lower end of the frequency response, where you have the most amount of energy, it's extremely difficult to remove those big fundamental resonances by acoustic means alone.

REG: Even just a few adjustable parametric equalizer coefficients will enable you to get control of the room's major disasters. It's a little on the crude side compared to the automated DSP systems, which as you know have scores or sometimes hundreds of parametric coefficients. But even analog equalizers with adjustable center frequencies let you attenuate those two or three discrete frequencies that are going "boom-boom."

RH: That leads me to the next topic, DSP room correction. Is DSP room correction a panacea that solves the problems we've been talking about?

REG: My experience with the DSP devices is that you can do amazingly effective things with them. When set up right, it's amazing how well they work.

RH: And what's also amazing is how dramatically different the sound is, when those resonances are removed. It's not a subtle effect.

PL: It's certainly something that anyone can hear. But some audiophiles are scared about this kind of equalization because it implies that you're shifting bits and doing all kinds of things to the signal, when everybody has been trying to keep the signal as pure as possible. What a lot of audiophiles still do not realize is that with digital technology you can do an awful lot that doesn't really change the musical information, add distortion, or create noise as the old EQs did. Room correction can precisely hit the room problems without adding distortion or noise. That, I think, is why the early equalizers did not work—they could never exactly hit the problem.

RH: Peter raised an interesting point about audiophiles having an aversion to signal processing. In the digital age, do we still want to keep the signal path as simple as possible, or does digital technology open up new frontiers that weren't available in analog audio? [This topic will be the subject of a future TAS Roundtable-RH]

PL: The goal here is to make a piano sound like a piano and a cello like a cello, with all the oomph and body you get from the real instrument. I've heard so many high-end audiophile systems where the midbass is simply removed. And then a lot of audiophiles are clapping their hands because it is oh-sodetailed, and the female voice is beautiful, and it's clean. The only problem is that the instruments don't sound like actual instruments anymore. And that's where the combination of sensible room treatment with sophisticated room correction can make the instruments sound like the real things. A piano is one of the most difficult things to reproduce, and with the

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proper EQ and proper setup of speakers you can really make a piano sound like it is in front of you. And I don't think that is possible unless you use both a sensible room treatment and very sophisticated DSP equalization.

RH: So we still need acoustic treatments and correct loudspeaker placement—DSP room correction isn't the magic bullet.

PL: If you have the chance to separate your low-frequency devices from your mid/high-frequency devices [i.e., a subwoofer with small loudspeakers], you should place your mid/high frequency devices where they give you the best possible imaging and the bass units all the way into the corner of the room. If the bass units are in the corner of the room the whole initial sound from the woofer is minimum phase. It is all going in the right direction at once. Whereas if you try to reproduce the low frequencies from your main speaker standing freely in the room, then much of the bass will go back into the corner of the room, reverse, and then come dripping back to you in the next 4, 5, 6, 10 milliseconds.

AN: That was the phenomenon the TubeTrap was designed to fix back in '83. It's a bass trap placed in the corners behind the speaker with a treble-range diffuser that faces forward into the room. There was no such thing as a hi-fi subwoofer back then. With full-range speakers, the wavefront would expand back into the corner and fold back out. Trapping that bass with a TubeTrap put this company on the map and has kept us alive for twenty years so far. Our approach is to absorb that bass so it doesn't get reflected back into the room, and to backscatter the mids and highs with a polycylindrical diffuser. That rear bass energy you're talking about is the same thing we've been addressing with Tube Traps for more than two decades.

REG: I'd like to introduce a slightly heretical thought here. If you have a resonance which you then remove by precise equalization, you've actually made your speaker in some sense happier. It does not have to work nearly as hard. The frequency range that had a 10dB boom has now become a range where basically the speaker can produce the required level with 10dB less output. Corner placement is actually nice for speakers because it insures maximum coupling to the room and minimum power input required to generate the bass you want. But, of course, you have to add some time delay if you're going to put the woofers in the corners.

AN: When you build a reverb chamber for acoustic testing, the classic speaker position to stimulate all the room's resonant modes is in the tri-corner [the point where two walls and the ceiling or floor intersect]. This is a room made from concrete two-feet thick coated by two inches of polished marble, and that has a reverberation time of fifteen seconds. The classic position for the measurement microphone to pick up all those resonances is also in a tri-corner.

The goal of speaker placement is to avoid stimulating room resonances, so I'm pointing out an inconsistency here with regard to corner placement of a subwoofer. The typical position to avoid stimulating resonances is 29 percent of the room's dimension off the floor, 29 percent in from the sidewall, and 29 percent in from the end wall. That is the most neutral position possible. I was recently reading a 1974 AES paper where the fellow produced a very smooth response in the room simply by moving the subwoofer around.

But now we have the opposite proposal of putting the subwoofer in the corner. It may have the benefits discussed, but it stimulates all the resonances. We have two diametrically opposed ideas. One is to put it at the minimum resonancestimulating location in the room and achieve fairly flat response, and the other is to put it in the corner and apply DSP room correction to correct for all the distortions that are introduced by stimulating the room modes. I think it's important that we be clear about these opposing perspectives.

PL: I agree they are opposing, but try to look at it this way: corner placement of the woofer will give you more total energy. Why will it give more total energy with the same amount of excursion from the cone? Simply because less of the energy generated by the speaker will be canceled by out-of-phase components interfering with in-phase components. So once you do precision equalization, you will get better timing of the signal. Really, you can say that the more SPL [sound-pressure level] you get at the listening position from a certain placement of the woofer system the less the signal you are receiving is out of phase and canceling. Of course, in most cases you end up getting too much energy, but that is so easy to take away with good DSP room correction. So that's my very simple argument for corner placement.

AN: If you have no acoustic treatments in the room and you have a DSP processor, what happens to the articulation in the room? You're still injecting energy into the room. You still have reverberation time. You still have the lack of intelligibility that you had before. You still have bass energy circulating in the room. People confuse DSP with intelligibility. Intelligibility is the ability of a room to rapidly respond to the dynamic changes of sound. We want a fast build-up and a fast decay. DSP doesn't address the decay rate factor of rooms, and neither does equalization. There is no electronic sound absorber for sale.

REG: None of us wants to try to correct your marble reverberation chamber with DSP—in the mids and highs. But in the bass, room ringing really can be cancelled out, at least for one listening position. The adapted DSP filter rings, too, but in reverse phase to the room ringing, so the combined result is that ringing is gone.

RH: I'd like each of you to comment on what you think is the single most important thing that audiophiles can do to improve the sound of their rooms.

REG: My feeling is damping the first reflections off the ceiling, floor, and sidewalls makes a fantastic difference. I have a preference for speakers with narrow radiation pattern, but that's a long, complicated subject. Most audio systems have way too much energy in the mid and higher frequencies bouncing around the room and not nearly enough of the first arrival. The first arrival is, among other things, where the imaging information is.

AN: We do rooms all day, every day, all over the world, for twenty years, and the first reflections are not what we fix first. The first thing we attack is something we call "head-end ringing." We shorten the vertical and lateral reverberation time in the bass by treating the space to the side of, and behind, the speakers. It's one of our trade secrets. By cleaning up head-end ringing, we dramatically expose low-level detail in the midrange and treble. I agree that absorbing first reflections improves imaging, but without treating head-end ringing, there's this slug of vertical and lateral shaking of air that oozes past the listener about a twentieth of a second after the direct signal and blurs musical detail and imaging. After we've addressed head-end ringing, then we control first reflections.

PL: I've done a lot of testing on the effects of reflections in rooms, and there was a big, big project in Denmark about twelve years ago, with a lot of companies involved in investigating effects of reflections in rooms. I had the pleasure of being a test person, where we could actually simulate the audible effect of the floor reflection, sidewall reflection, ceiling reflection, and so on independently. The single most disturbing reflection in the room is the floor reflection. That is what makes the speaker sound like a radio and not like the actual event. The second worse reflection is the ceiling reflection. Sidewall reflections, if they are sufficiently delayed (more than about five milliseconds) and are left/right symmetrical, can be actually beneficial to the sound. But if your speakers are very close to the sidewalls, you have to kill the side reflections. But do not be too concerned about the sidewall reflections. The floor reflection absolutely must be handled, followed by the ceiling reflection, either by absorption or diffusion.

AN: Well, I've been there, and diffusion blurs imaging. Ceiling diffusers blur imaging, and they add an artifact because they're a bunch of resonators. All of our ceiling traps have reflectors in them, but the reflectors are always offset and point to the back of the room. Diffusers are energy storage devices, are tonal in nature, and create incoherent reflections, which mask the perception of coherent reflections.

PL: I'm sorry. I didn't express myself properly. I was not thinking about diffusers as the devices you can buy. I'm thinking something on the ceiling that will prevent the first reflection from reaching you directly.

RH: I'd like to conclude by adding my own comment about the single most effective technique for improving the sound of your room: loudspeaker placement. Through loudspeaker placement you can control the amount of bass, overall tonal balance, image specificity, and soundstage width. Speaker placement has its limitations, and the sound will still be greatly influenced by the room, but I suspect that most readers' systems could be improved by better speaker placement. ■

**Robert E. Greene** joined the writing staff of The Absolute Sound in 1983 and has been working as a music and later an equipment reviewer ever since. His interest in audio goes back to his early teens, and, like many teenagers of the time, began to build his own equipment. He began studying the violin on his fourth birthday, and continued his musical training with the idea of becoming a professional violinist until his early twenties, when he decided to pursue his other big interest, mathematics, as a profession. He is a long-time member of the Chamber Orchestra at Saint Matthew's. Dr. Greene has been a mathematics professor at UCLA even longer than he has been a TAS writer, and has written nearly one hundred research papers on mathematics and several books with titles like Function Theory on Manifolds which Possess a Pole (with H. Wu)—not a NY Times best seller! He also teaches an honors course at UCLA in acoustics and psychoacoustics that he developed to introduce music students to technical aspects of sound, and engineering students to the relevance of science to music. Small-room acoustics for audio is one of his special interests and he has been reviewing DSP devices for room correction in TAS for a number of years. As a real L.A. person, he has a screen credit: Violin instructor to Russell Crowe in *Master and Commander: The Far Side of the World.*

**Peter Lyngdorf** is a major figure in high-end audio manufacturing and retailing. Peter's interest in music and audio began at an early age, and by high school he was designing and building loudspeakers. In 1975, he founded AudioNord International, a Denmark-based hi-fi retail and distribution company that has grown to include subsidiaries in seven countries encompassing 46 retail stores. Returning to his fascination with loudspeakers, Peter founded DALI Loudspeakers in 1981. He has owned several prominent high-end companies, including Snell Acoustics from 1990–1997 and NAD Electronics from 1992–1998. At Snell, he developed the world's first full-range DSP room-correction device with Dr. Radomir Bozovic. Lyngdorf and Bozovic later co-founded TacT Audio, offering DSP room-correction products and the world's first fully digital amplifier (1998). He lives in Denmark with his wife and three children, and enjoys sailing and bicycling. His greatest ambition is "to reproduce music perfectly in any home."

**Arthur Noxon, P.E.** is a physicist and licensed acoustical engineer, and the founder and president of Acoustic Sciences Corporation (ASC). The patented TubeTrap acoustic product line was invented by Mr. Noxon, after noting a lack of off-the-shelf low-frequency sound-control devices. Since 1983, he has developed a wide range of renowned acoustic and soundproofing products for commercial, residential, and industrial applications, including critical listening and recording environments. He has been published in the AES professional journal, and has contributed a variety of articles for consumer and trade publications. He holds Master's degrees in Mechanical Engineering/Acoustics and Physics, and currently resides in Eugene, Oregon.