Parametric Acoustics

The Case for the Parametric Method of Acoustic Treatment

Third Edition*

By: Michael Fay

Abstract

The topic of architectural acoustics has been documented and carefully studied for more than a century. Historically, most absorptive treatment materials and products have offered a relatively *broadband* approach to managing reverberation in a room. While this basic approach has changed little, new acoustical goals, priorities, materials, test lab findings, and training suggest this singular approach needs updating.

The Parametric Acoustics thesis does not challenge the physics underlying traditional acoustic theory. Rather, it offers a fresh perspective on how new materials can and should be deployed. For instance, the development of new absorption materials and products can and should provide a more specific, *tuned* range of frequencies; particularly those within the bottom three octaves of commonly used and heard sounds. Why? Because of the massive amounts of full-bandwidth energy being pumped into rooms deploying our modern loudspeaker technologies. Much of this energy is left untouched by generic acoustic materials.

This paper expands on the T_{60} Slope Ratio thesis[1] by providing methodology, commentary, and examples for specifying acoustic treatments as band-limited tools. The T_{60} Slope Ratio (TSR) is represented symbolically as $T_{60}SR_6$. The calculation delivers a relational score (Figure 1) using the two extreme time values - from the six octave centers - between 63 Hz and 2 kHz. The score is calculated by dividing the longest T_{60} by the shortest T_{60}, regardless of octave.

Slope Ratio Score	$T_{60}SR_6$ Scoring & Grading Matrix	
	1.00 - 1.10	Good
	1.11 - 1.20	Optimal
	1.21 - 1.30	Good
	1.31 - 1.50	Fair
	1.51 - 1.70	Poor
	Above 1.70	Bad

Figure 1 – The $T_{60}SR_6$ or TSR Mean Opinion Score grading matrix.

This discourse outlines how and why a *Good* to *Optimum* TSR *grade* can be achieved in almost any *sound-critical* space. To that end, the next level of architectural acoustic refinement is proposed: PMAT - the Parametric Method of Acoustic Treatment.

While the best practitioners in architectural acoustics already understand, and may implement similar principles, the PMAT concepts are not widely considered or applied.

* Following its original publication[2] in May of 2021, I was notified of an error in the data tabulation in what was then Figure 12. The *second* edition of this thesis provided the corrected values, which are shown in Figure 5 below. Also, five new sections were added or updated.

My new book *Acoustic Essentials for Architects*, published in May 2025, has prompted this *third* addition. It includes refining and adding to the existing information, syntax corrections, new products and graphics, and reordering some sections for better flow and clarity.

Background

Professional-grade loudspeakers are designed and optimized to perform as flat (magnitude) or nearly flat, audio output devices. Therefore, shouldn't acousticians be designing the same nearly-flat timbre into the rooms in which these loudspeakers operate?

TSR theory prescribes a set of design and performance goals that encourage us to craft a nearly flat reverberant room response but doesn't offer any specific guidelines to achieve those goals. PMAT adds methodology to this new model of refinement in architectural acoustics.

The idea of a generalized, single number reverberation time is merely a convenient way of stating a room's averaged mid-band (500 Hz and 1 kHz) reverberation time (T_{60} or T_{30}). For most end users, acoustics boils down to this single-number concept. It's not uncommon to hear a comment like this: "We have way too much reverb in this room for the style of music we're trying to present. It seems like it lasts about two seconds." Knowingly or not, this commentary is almost always referring to the mid-band reverb time (T_{mid}) in their room.

Unfortunately, these remarks often lead to the ubiquitous, 1" or 2", fabric-wrapped fiberglass panels, or similar foam products. If all you need to do is reduce reverberation at 500 Hz and above, such products may be all that's required.

Notice the common theme with each of the products shown in Figure 2: Very low absorption coefficient (α or alpha) values at 250 Hz and below, then a quick rise to much more useful numbers, starting at roughly 500 Hz

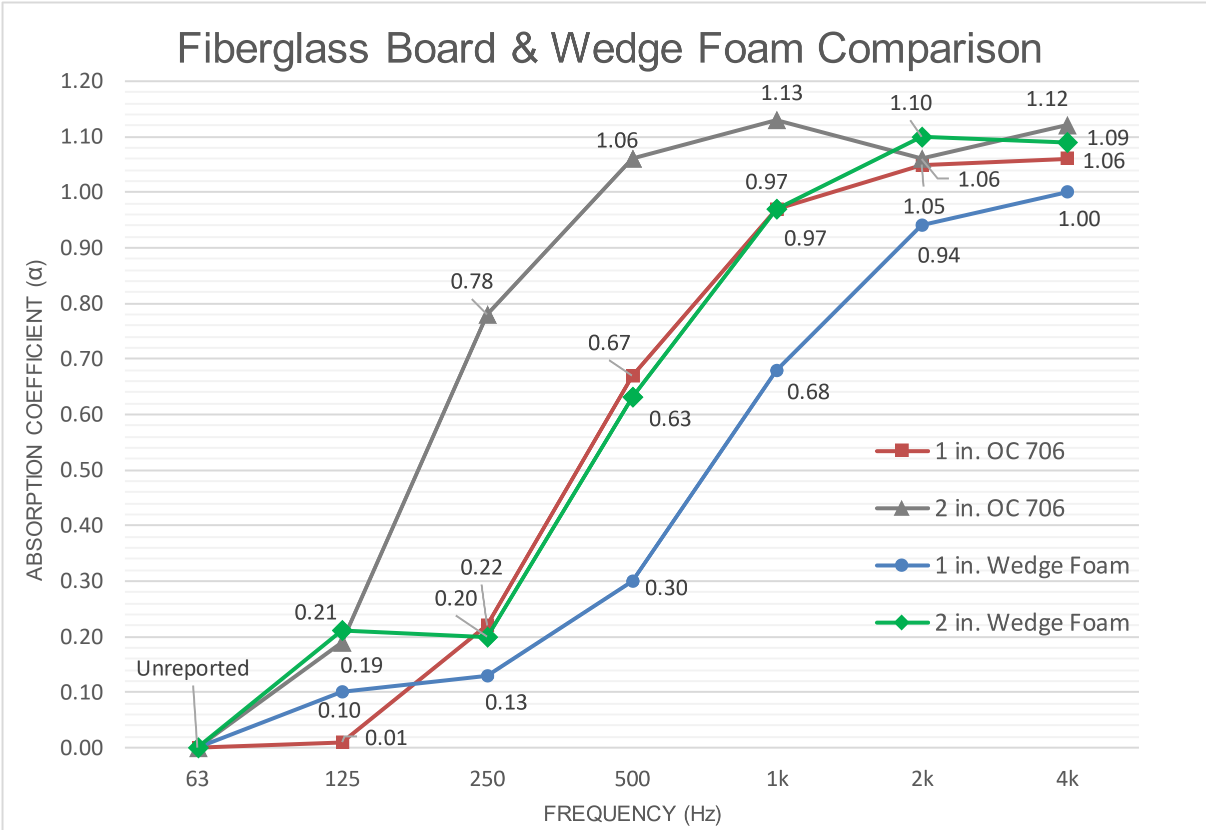

Figure 2 – Line charts for four commonly-used acoustic wall treatment materials: 1” & 2” Owens Corning 706 fiberglass board, and 1” & 2” versions of Auralex Studio wedge foam. The fiberglass board is usually covered with an acoustically transparent fabric. Such fabrics contribute very little additional absorption.

There are various T_{60} line charts shown below that have an inverse slope or shape compared to these common treatment products. Essentially, the materials shown in Figure 2 perform as 500 Hz, low-pass, reverberation and resonance filters. Or, exactly the opposite of what a room might need most.

Line Charts

Using line charts[3] is probably the easiest way to visualize and understand reverberation time at the various frequencies of interest. They’re also good for showing alpha data.

Many of the line charts presented in this thesis use the standardized, one-octave frequency centers, between 63 Hz and 4 kHz. While excess 4 kHz reverberation is rarely an issue, it’s shown because most manufacturer’s spec sheets extend the range of their α data to that frequency. 1/3-octave bands can and should be used if a room exhibits an unusually strong or asymmetrical distribution of resonance or reverb between the octave centers.

Describing how to gather the necessary acoustic data is outside the scope of this paper but know that modern FFT measurement platforms (i.e. Smaart and SysTune) capture impulse response data that can be analyzed at both octave and 1/3-octave resolution.

Absorption Coefficients Above 1.0

The sound absorption coefficient is the fraction of sound energy absorbed by a material. Expressed as a value between 1.0 = perfect absorption (no reflection), and 0 = zero absorption (total reflection). The value varies with frequency and angle of incidence, determined experimentally.[4]

If you're disturbed by the various charts in this document showing alphas higher than 1.0, know that I am aware of the arguments for and against. The data used herein comes from the various manufacturers cited. If preferred, round down to 1.0. By lowering to a max α of 1.0, your results will merely reflect the need for more material than necessary.

PMAT Defined

PMAT theory suggests that acousticians specify products and materials that not only perform broadband absorption when required, but also perform specific work within various 1- to 2-octave bands. Think of these products as 1- to 2-octave, cut only, parametric absorbers (room-tone equalizers).

An electronic parametric equalizer offers separate controls for frequency, bandwidth (Q), and level. When properly applied, these are powerful tools. If we adapt those same three parameters to material alphas, we introduce a completely fresh, band-specific way of treating excess reverberation and resonance.

- Frequency: The center frequency of maximum absorption offered by the treatment material.
- Bandwidth: How broad or narrow is the Q? PMAT theory suggests that when the α rate is reduced by 25% or more - one octave above and below its peak α - and continues to fall off on a similar trajectory, such products or materials may be well-suited for PMAT applications.
- Level: Higher alphas are better. The higher the α, the more effective the product is at absorbing energy at that specific frequency. This translates to less material being needed per frequency band, and potentially, lower overall cost.

What's So Special About the *Slope*?

In a well-behaved room, regardless of its T_{mid} time, the incline or slope of its T_{60} line chart will gradually decrease, beginning with the lowest frequency analyzed. This is a natural and expected profile, primarily controlled by a combination of room size and geometry, finish materials, and air absorption. For rooms equipped with powerful, full-range sound systems, TSR theory suggests the slope should be nearly flat - with only a very gentle downward tilt – from 63 Hz to 2 kHz.

Beyond simply having excess low- (LF) and very low frequency (VLF) reverb and resonance, when a room presents an *asymmetrical* or *double knee* slope (see the broad red line chart at the top of Figure 3), any of the six octaves may contain a much longer or shorter reverb time than its neighbor. When looking at a well formed T_{60} chart (see the broad green line chart in Figure 3), there should be no sharp knees. Ideally, such anomalies can and will be addressed using PMAT solutions.

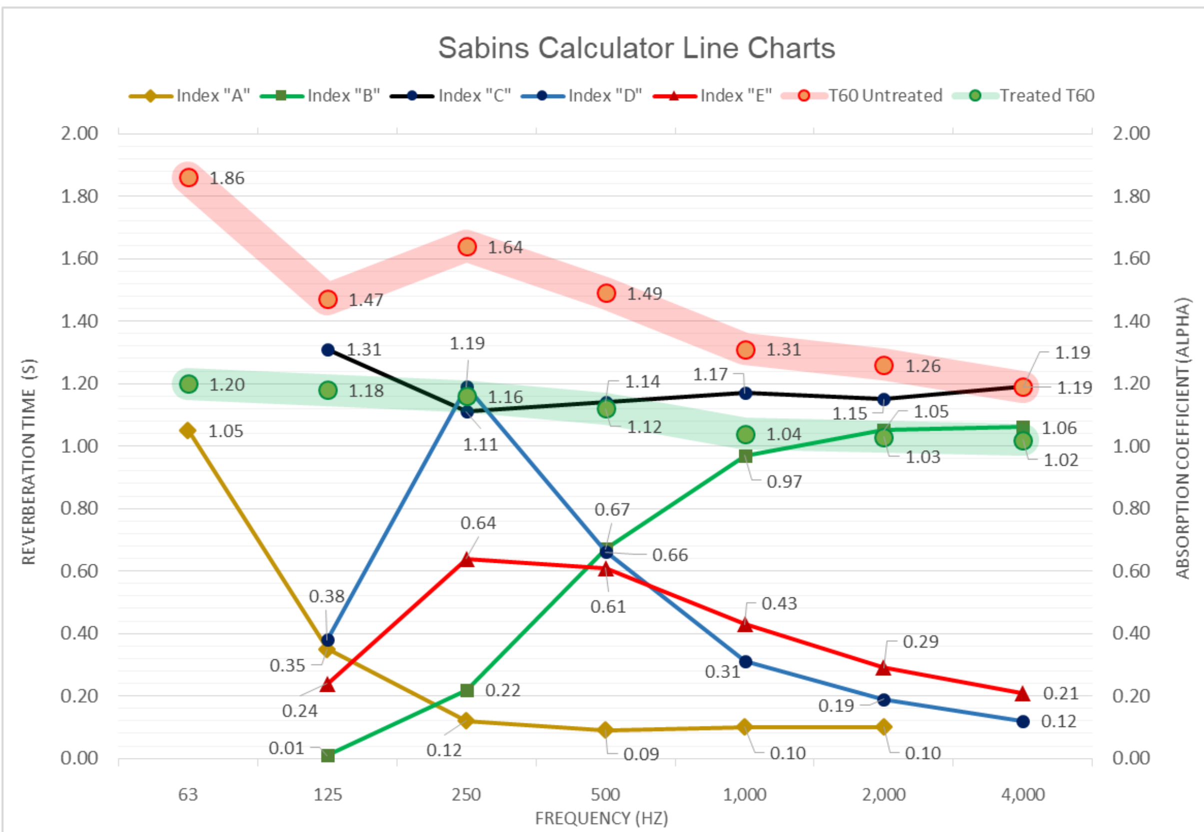

Figure 3 – From the sabins calculator shown in Figure 14 below - A graphic representation of the before and after (broad red and green lines) T_{60s}. The thin lines show the absorption coefficients for each of the materials used to achieve an Optimal TSR grade.

Needs Analysis

Every room or building has some inherent acoustic "sound" or tonal character. A few are complementary to their various sound-related functions, others are obviously bad - even to the sensitivities of the non-professional. The vast majority fall somewhere in between, and do not fully reveal their strengths or weaknesses until certain sonic activities are introduced.

The exceptional rooms generally go unnoticed to all but a few, whereas really bad rooms seem problematic to almost everyone; usually because they have too much reverberation for almost any application.

One bad example is a high school gymnasium I reviewed many years ago. There was so much reverb the coaches couldn't hold basketball or volleyball games, or practices. They couldn't communicate with the players. The %ALcons score was 33, which translates to an STI score of 0.30; both are rated to be at the border between *poor* and *unacceptable* results. Figure 4.

STI	0 - 0.30	0.30 - 0.45	0.45 - 0.60	0.60- 0.75	0.75 - 1.00
	Unacceptable	Poor	Fair	Good	Excellent
%Alcons	100 - 33%	33 - 15%	15% - 7%	7 - 3%	3 - 0%

Figure 4: This table shows the grading scale for speech clarity and intelligibility based on STI and %Alcons calculations. These are industry standard guidelines.

For this building the obvious solution was lots of broadband absorption. Because this wasn't a sound-critical venue, and didn't require custom or specialized treatment, the solution was the application of about 9,000 ft^2 of International Cellulose K13, sprayed on the ceiling – to a thickness of 1.5".

While this was an extreme example, most venues have more specific needs. If we're within about one second of an appropriate T_{mid} target it is suggested here that alone broadband absorption is not the only, or best answer.

As stated earlier, most broadband treatment materials, like those shown in Figure 2, provide inadequate absorption at or below 250 Hz. This is a problem because these days many performance, worship, and entertainment venues can't dissipate the massive amounts of LF and VLF energy as quickly as it's being produced by the loudspeaker systems.

To further complicate matters, it's also likely that the 63 Hz and 125 Hz octaves aren't the only ones with resonance and/or reverberation that's too long - relative to their neighboring frequencies. When such scenarios exist a room's reverberant character is even more out of balance and should be acoustically *equalized*.

For example, consider the survey done by Dr. Niels Adelman-Larsen (NAL) in his book *Rock and Pop Venues - Acoustics and Architectural Design*.[5] Figure 5 represents an aggregate of the ten best and worst venues for Rock and Pop music in Denmark.

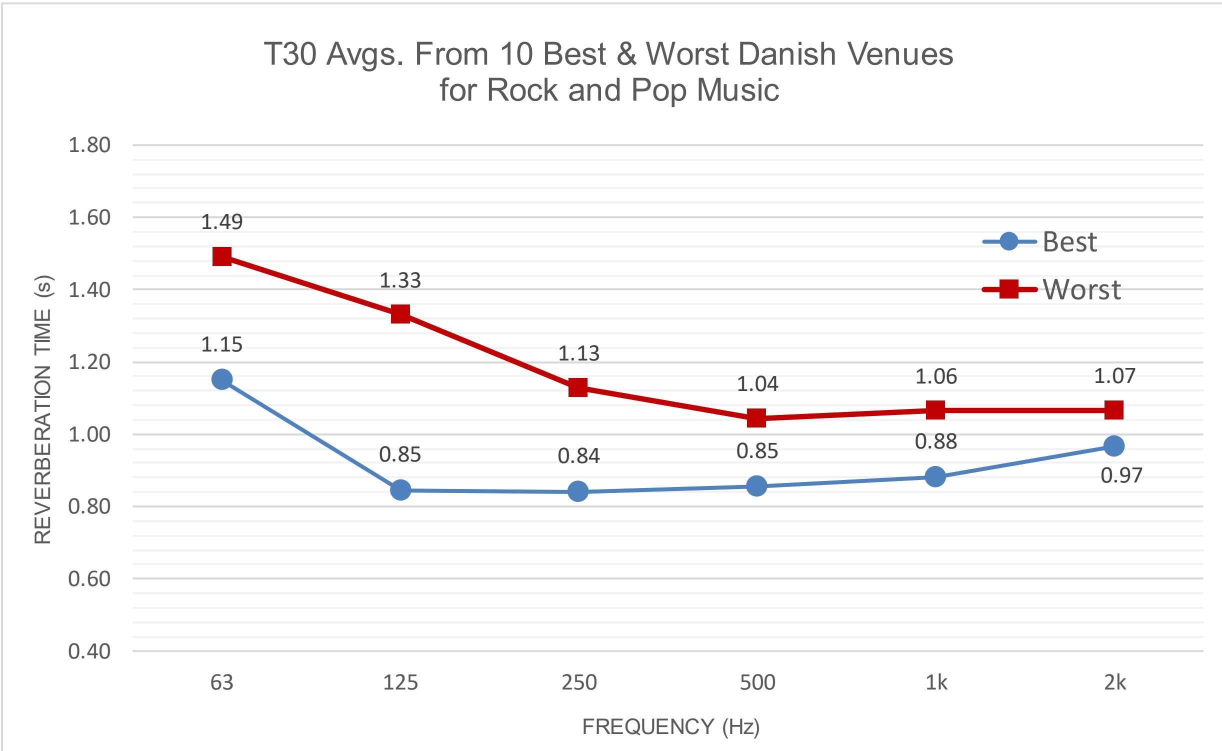

Figure 5 – This is a correction to the Figure 12 chart that was published in 2021. It shows the average T_{30s} of the 10 best and worst venues in Denmark.

Pay close attention to the T_{30s} at 63 and 125 Hz in these 20 venues. The T_{mid} for the *Best* rooms is 0.87 seconds, and for the *Worst* rooms it's only 1.05 seconds. The point: One would think a 1.05 second room should work well for amplified rock and pop music. However, acoustic problems often lie well below the T_{mid} bands. They lurk in the bottom two or three octaves. This is where these rooms have trouble dissipating the constant flood of LF and VLF energy.

Even the chart labeled Best, represents a $T_{60}SR_6$ score of 1.37, which translates to a *Fair* MOS (mean opinion score) grade. For the Worst venues, the average score is 1.43, which also gets a Fair grade, but it's a mere 0.07 seconds away from being considered poor – even before the audience arrives.

Like most reverberation measurements, these times were captured in unoccupied rooms. "The data shows that the absorption coefficients of a standing audience are five to six times higher in the mid-high frequency bands, and that there is very little absorption in the low frequencies".[6a]

The takeaway is this: A room that has a *Fair* TSR grade when empty, can easily turn into a *Poor* room when occupied. Therefore, it's important to start with the best possible TSR score so when the room is fully occupied, the slope ratio is less impacted for the worse.

While twenty venues is a relatively small sample size, the trend is obvious: none of these rooms were designed with our modern musical tastes and technologies in mind.

Is there an ideal T_{60}?

There is no ideal T_{60} or T_{mid}. The best anyone can offer, based on static rooms without variable acoustics (VA), are suggestions based on the music genre and the volume (size) of the room.

For example: Figure 6 briefly summarizes the results of the research[5, 6b] done by NAL, which concludes there are two important factors to consider for rhythmic music genres (i.e. rock, pop, jazz, punk, hip-hop, Latin, and contemporary worship, etc.): room volume and T_{60} at 125 Hz.

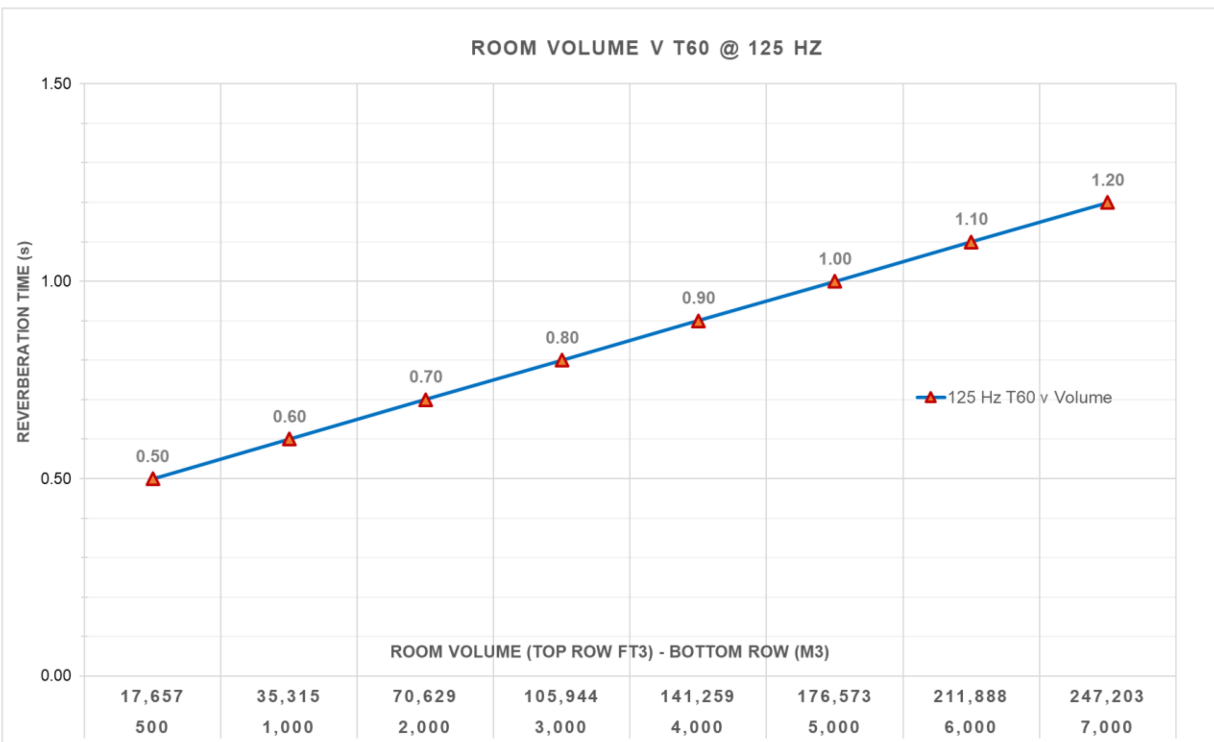

Figure 6 – This chart shows the trend line that represents suggested 125 Hz T_{60s} for empty halls of various volumes. The volumes are represented in cubic meters. In cubic feet the range is roughly: 17,665 - 247,200 ft^3. This trend line continues on a fairly linear path up to 50,000 m^3 and beyond. Example: A 92' x 55' x 35' room has a volume of 177,100 ft^3, or roughly 5,000 m^3.

These two quantifiers were distilled from RIR (room impulse response) measurements taken in 20 small to mid-sized halls, and 33 engineer/musician surveys[5, 6c] NAL conducted in Denmark. They conclude that – depending on room size - a wide variety of rhythmic music genres sound best when performed in rooms with about one-half second to one and one-quarter seconds of reverberation/resonance at 125 Hz. His various research papers[6a, b, c] place a great deal of emphasis on these two fundamental values.

The Wave/Ray Duality of Sound

Sound behaves differently depending on wavelength (frequency) and the *environment* in which it is propagated. Dr. Manfred Schroeder referred to the frequency at which rooms go from being resonators to being reflectors/diffusors as the *crossover frequency*. We now call it the Schroeder frequency (F_S).[7]

The formula for determining the Schroeder Frequency is F_S = $K\sqrt{T30/V}$. T_{30} is the T_{mid} reverb time, *V* is the room volume in feet or meters, and *K* is the constant. *K* = 11,885 (USC) or 2,000 (SI). The environment mentioned above is an enclosed room, regardless of size. Together, room volume and its T_{mid} reverberation time determine the F_S point.

F_S defines the initial (lowest) frequency, beyond which all lower sounds behave like waves. Once you know F_S it's necessary to multiply that frequency by four (4) to determine the upper limit ($4F_S$) of the *transition zone.* $4F_S$ establishes the point at which all higher sounds behave like light rays.

The transition zone consists of frequencies with ambiguous behaviour; neither fully resonant/modal, nor completely diffusive reverberation. This is not a hard transition but a gradual one, which occupies about two octaves of sound, and includes all frequencies between F_S and $4F_S$.

Application: If F_S is 70 Hz, then $T_{60/30}$ measurements of a room are only fully reliable above 280 Hz. It takes a very large room – over one million ft^3 - to reliably evaluate true reverberation at, or near, 63 Hz. In other words, just because you have excess reflected energy in a room at 63 Hz, or 100 Hz, doesn't mean that the energy is reverberation. More likely it's modal resonance.

Note: There is no such thing as a r*ay* or *particle* of sound. The ray descriptor is used just for simulations. All sound travels in waves. Also, room modes don't stop at F_S or $4F_S$, they extend over the entire audible spectrum. At and above $4F_S$ modal densities are so high that the computational math becomes impossibly complex. So, to simplify things, we transition to geometric acoustics based on optical principles. If we have accurate input data, and could easily crunch the numbers, our prediction models would use the wave equation for the entire audible spectrum.

In his recent article on the Schroeder Frequency[8], Pat Brown calls the transition area between F_s and $4F_s$ the *diffusion zone*. These are the frequencies that behave a little like both waves and rays.

Generally, reverberation produces the same diffused sound levels for all listeners. It has no specific direction of energy flow.

On the other hand, room modes (standing waves or eigentones) produce dramatic level changes from location to location - often separated by only a few feet. Figure 7 is a great visual. It tells the story better than a thousand more words could. It also helps explain why one person will complain that the bass guitar is overwhelmingly loud, while someone sitting just a few feet away may observe that there is not nearly enough.

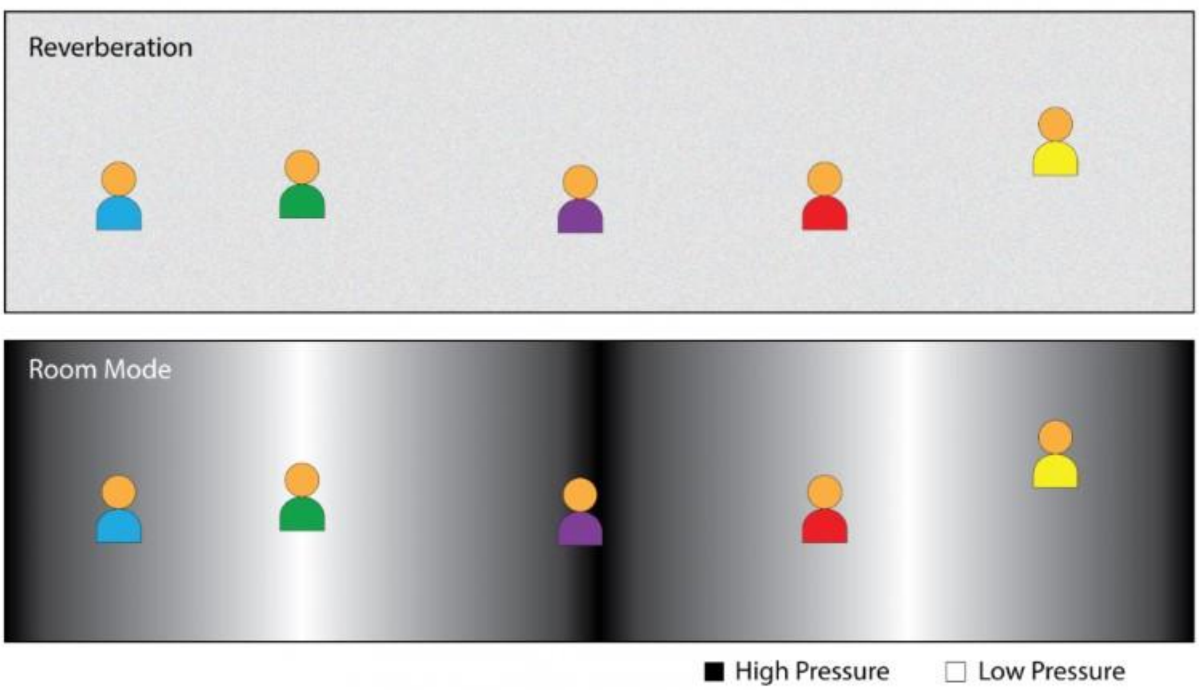

Figure 7 – Reverberation envelops everyone equally. On the other hand, room modes cause extreme loudness variances in both direct and reflected energy - from one small area to the next. Put in simple terms: high pressure equals way too loud. Low pressure equals near silence. Graphic courtesy of SynAudCon.[8]

Why is the wave/ray duality relevant to PMAT? For truly effective results, acoustic materials need to be selected based on the frequencies needing treatment. “Modal zone resonance (at and below F_S) requires active trapping such as found in diaphragmatic panels, bass traps, and Helmholtz resonators. Diffusion zone frequencies (F_S to $4F_S$) often respond best to physical objects such as wall shape, furniture, and complex surface finishes with deep relief. Only at, or above $4F_S$, can we expect adequate performance from the *typical* acoustic treatment materials such as carpet, padded chairs/pews, fiberglass wall panels, and people.”[8]

Even though room modes aren’t technically reverberation, the fact they exist, and may resonate longer than all other low-, or mid-frequency reverberation, means they too can *muddy-up* an audio performance or presentation. Dominant room modes (typically Axial modes) must also be acoustically treated to improve the sonic uniformity and music clarity of a sound-critical space.

Pay Close Attention to Absorption Coefficient Specs

The α values of any treatment solution should have a certified laboratory report that can be easily accessed from the manufacturer’s website. The basic assumption is the data follows standardized ISO or ASTM testing procedures. If the data isn’t on their site, call them and ask for it.

First caution: When evaluating treatment materials, check whether metric or imperial sabins are being stated. The *sabin* is the unit of measurement used to describe a unit of sound absorption. “One square meter of 100% sound absorbing material has a value of 1 metric sabin. One square foot of 100% sound absorbing material has a value of 1 imperial sabin.”[4] Therefore, the obvious conflict is this: it takes 10.76 square feet of material to equal 1 square meter of the same material, so it’s easy to make a huge calculation error if you don’t know which one you’re working with.

Second caution: Beware that some manufacturers state the absorption data per square foot (or meter) of exposed surface material on some items, while for other products they report the data for the panel as a whole. If the data is clearly marked as representing a *per panel* or *per device* value, it’s easy to calculate back to a value that represents the α per square foot or meter. Example: A 2’ x 4’ panel has 8 ft^2 of surface on one side. Divide the per panel sabins total by 8 to get the α per square foot.

One way to spot the difference is to watch for alphas that are well above 1.0, and often above 2.0. If you see this, there’s a good chance the data is being expressed for a whole panel.

Current High Q Products

Wouldn't it be great if there were lots of treatment options based on specific, octave-band absorption? And, wouldn't it also be cool if those options included both velocity- and pressure-based absorption schemes? If you're unfamiliar with the differences between velocity- and pressure-based absorption, this short article[9] from GIK Acoustics is quite concise.

Finding existing products to fit the specific needs of a project can be difficult. I've spent considerable time looking, and will share several examples below. Hopefully, in the near future, more manufacturers will see the value in developing band-limited absorption products.

When considering any treatment products, it's important to determine how the manufacturer's absorption data was tested. Some companies provide their α data based on impedance tube measurements, which only give *normal* (perpendicular) incidence alphas. A very large reverberation chamber is needed to accurately measure *random* incidence sound absorption coefficients.

Notice the similarity between the shape of the T_{60} line charts and the alphas of the potential treatment solutions highlighted below in Figures 8 & 9. This is what we're looking for from potential PMAT products. The longer the T_{60} at any given octave center, the greater the alpha we want at that same octave center.

Remember, it's necessary to view the charts below as inverted, parametric cut filters. In other words, the higher the peak α the more absorption, and therefore the deeper the acoustical cut.

Both RPG Acoustical Systems and GIK Acoustics show dedicated bass trap products that represent what we're looking for at 100 Hz and below. These narrow-band examples show significantly lower alphas above and below their peak absorption frequency.

RealAcoustix[10] offers multiple options that have been tested in the large chamber at NWAA Labs[11] in Washington. Figure 10 shows one example from their BassMod series of diaphragmatic absorbers.

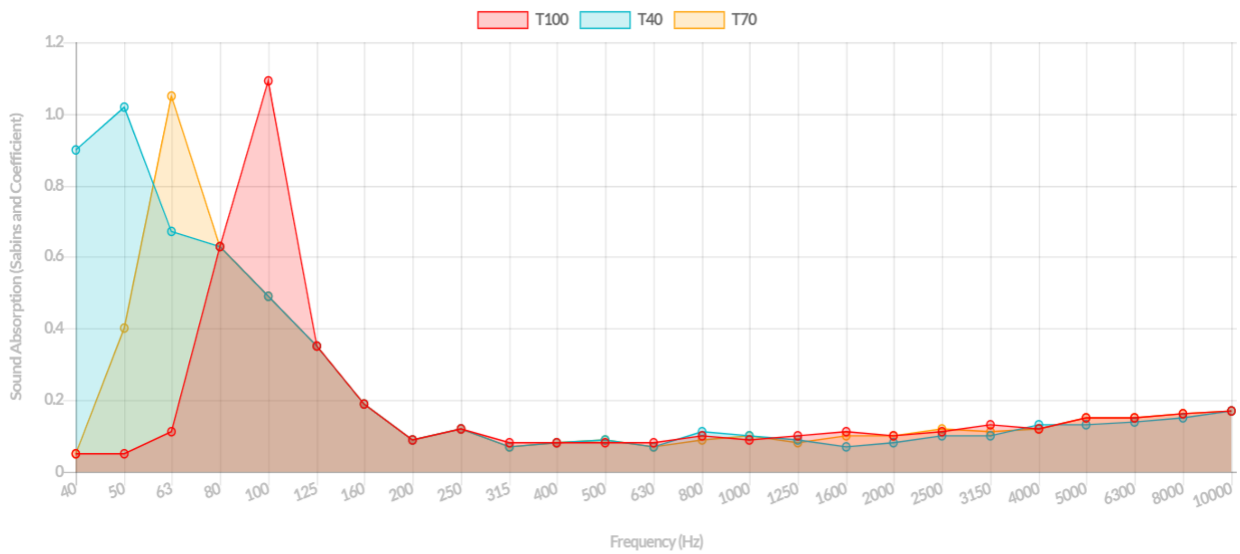

Figure 8 – Three, tuned, GIK Scopus series bass traps. Note the very narrow bandwidth (Q) of each model. While the names they give to each trap suggest the center frequency of best performance, the data sheet shows something slightly different. Source: GIK Acoustics

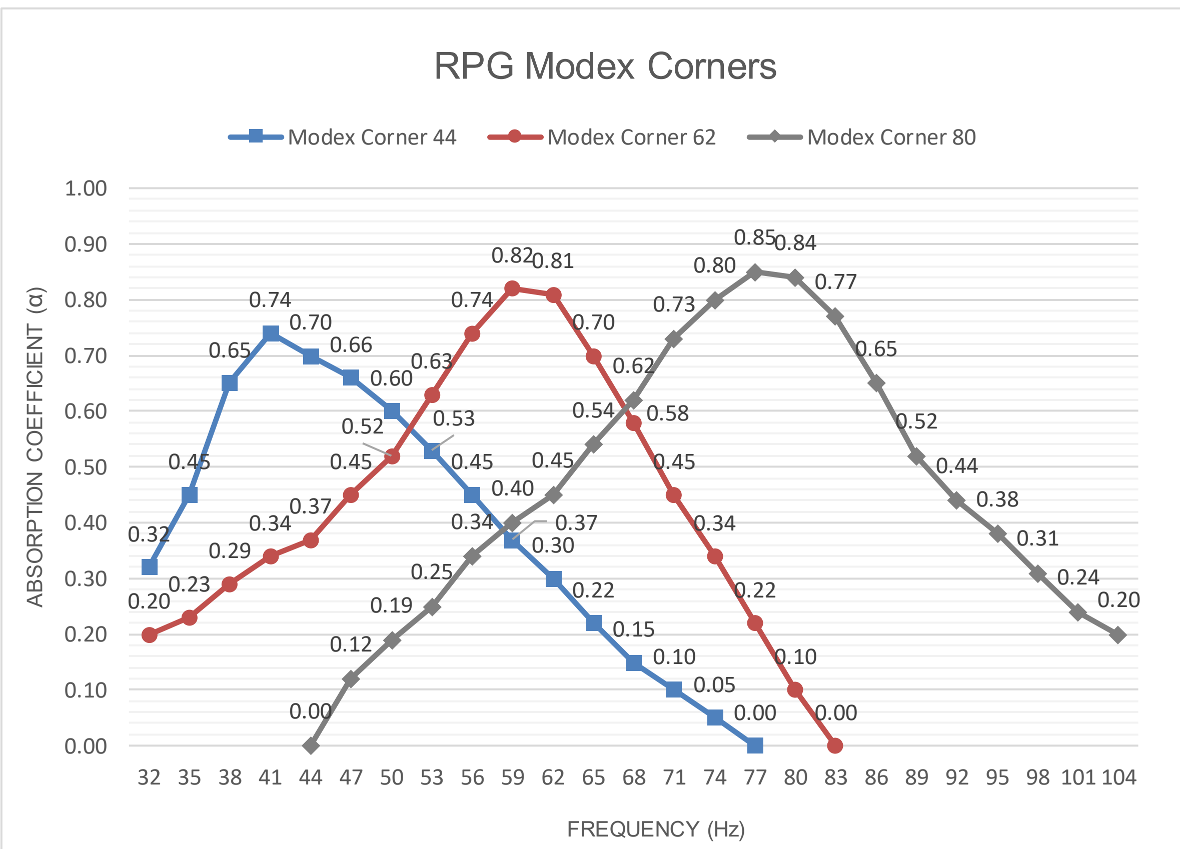

Figure 9 – Examples of three RPG Modex Corner bass traps with peak alphas at 41, 60, and 77 Hz. Again, notice the very narrow Q of each.

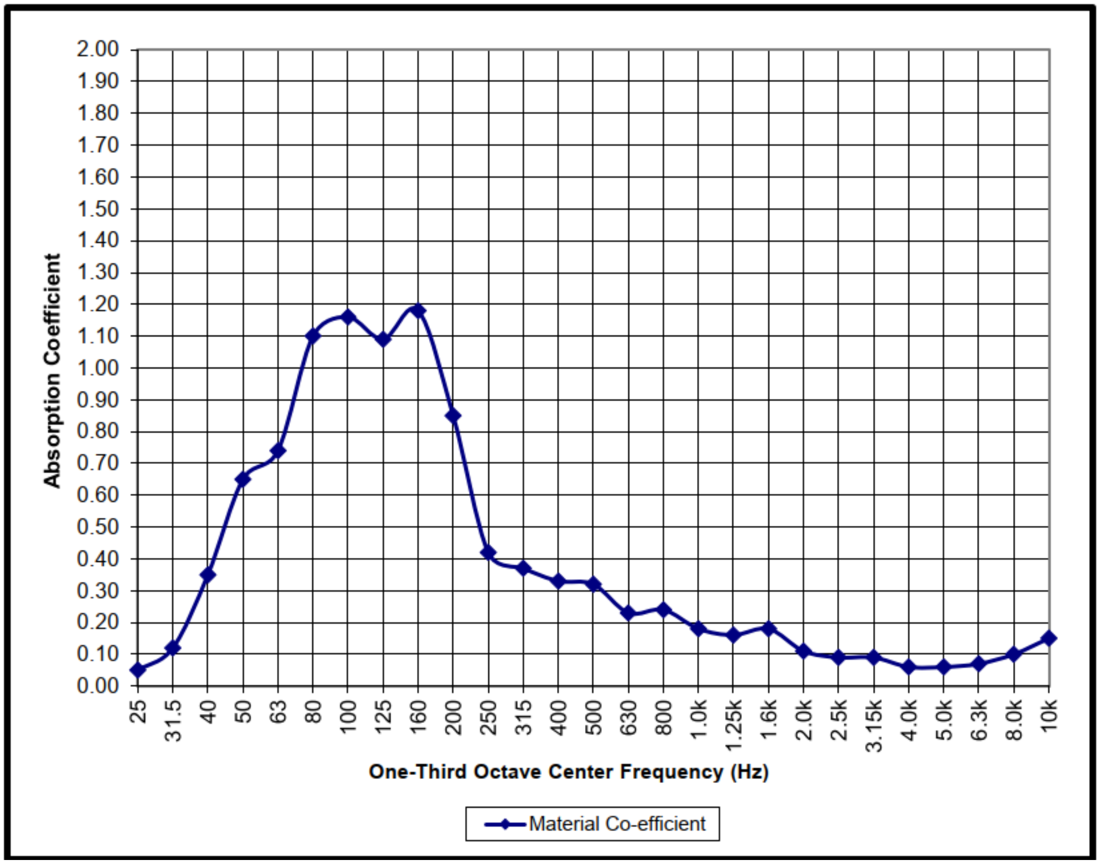

Figure 10: The RealAcoustix BassMod 4848-6. This is a particularly good wide-bandwidth PMAT pattern for two reasons: It provides a good to excellent alpha profile between 50 Hz - 225 Hz, and it gets out of the way of other mid- and high frequency treatments starting at 250 Hz. This is a 48”x48”x6” module.

Figures 11 and 12 show good PMAT treatment options that focus their absorption profiles between 125 Hz and 500 Hz. At 125 Hz the RPG Modex LF product has a very nice α chart, as does the Real Traps Mega Trap. Stepping up to 250 Hz, the Kinetics Noise Control (KNC) - Sereno 2/10 2” FG - perforated wood panel also fits nicely into the PMAT scheme. Notice how quickly it falls to 0.38 at 125 Hz and 0.66 at 500 Hz. You can see how this panel is used to address the 250 Hz slope asymmetry in Figures 14 & 15 below.

At 500 Hz the best example I’ve found is the MBI 2” Bandit series. It has a slightly broader Q at 1 kHz, but overall, it fits well into the portfolio.

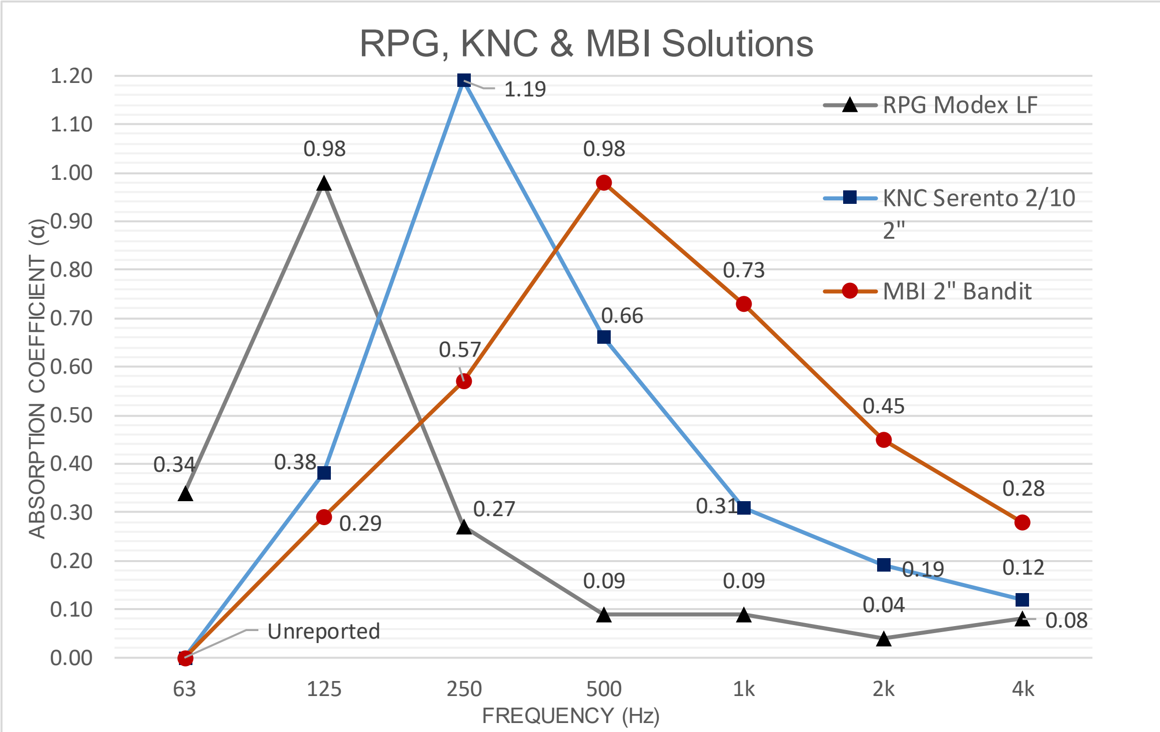

Figure 11: Each of these products show excellent examples of the mid- to high-Q profile needed at 125 Hz, 250 Hz, and 500 Hz.

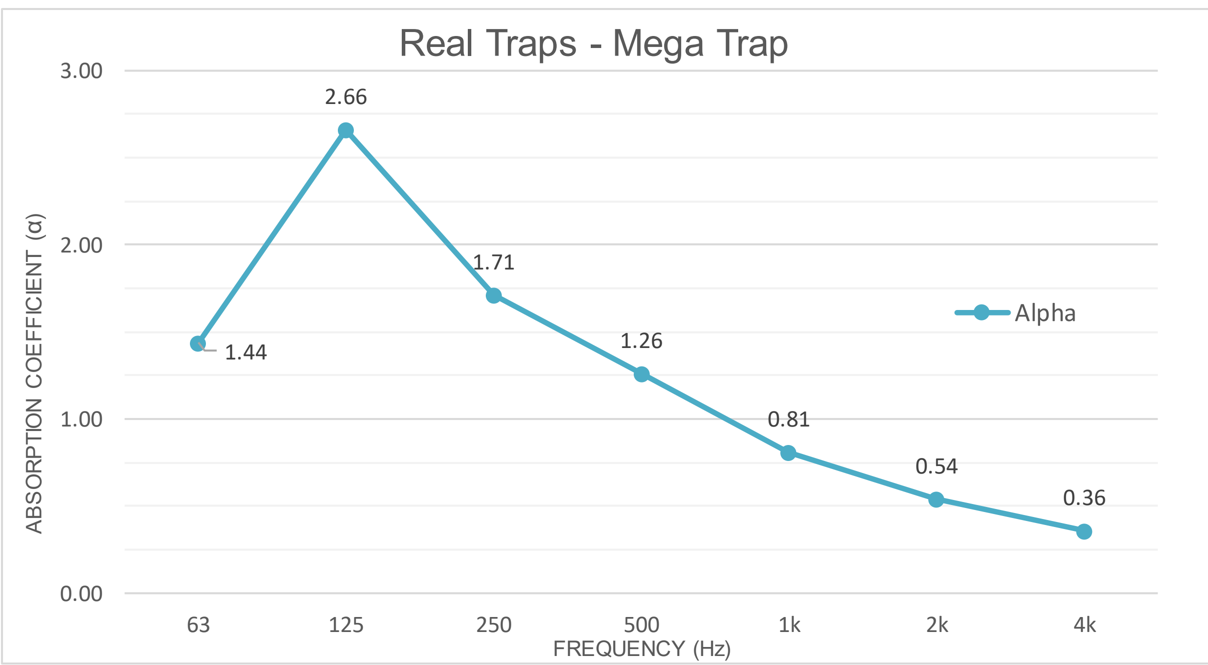

Figure 12: The Real Traps - Mega Trap is another interesting 125 Hz product. It boasts 2.66 sabins of absorption, per ft^2, at 125 Hz, and an alpha well over 1.0, from 63 Hz to 500 Hz. As verified by the company, these are per ft^2 values, not per device.

Figure 13 takes us up to 1 kHz: The 1.2” RPG BAD panel actually peaks slightly lower at 800 Hz (not shown in 1 octave resolution), but it’s the closest option I’ve found for addressing 1 kHz. It’s best applied when a little broader (lower Q) PMAT solution is needed.

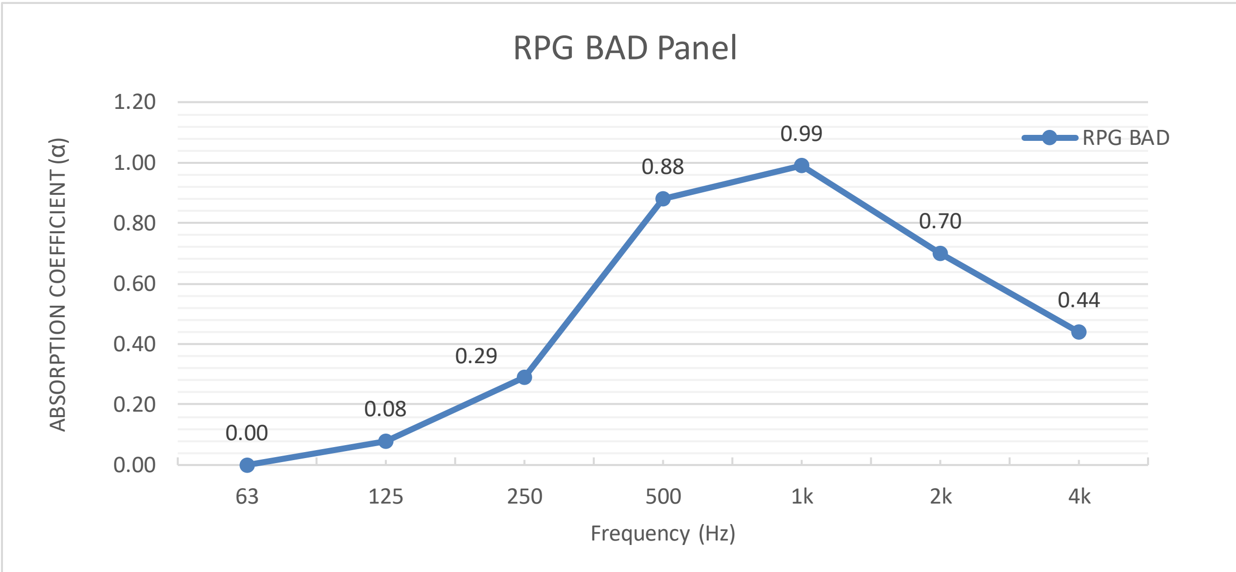

Figure 13: This RPG BAD panel is down more than 25% at 2 kHz but only drops about 11% at 500 Hz.

I have yet to find anything that specifically addresses 2 kHz and above, but alone those frequencies are rarely much concern.

By now you should begin to see how the PMAT theory is applied. As with all dedicated acoustical products, the application of these treatments needs to be well distributed and properly positioned to maximize their effectiveness.

Adding Sabins from Different Materials

How do the various α values add together - at any given frequency - when working with materials having disparate alphas? The answer is to convert the various alphas into total sabins of absorption at each frequency of concern.

Let’s say you have 128 ft^2 of a treatment that has an absorption coefficient of 0.60 at 500 Hz, and 128 ft^2 of another product that has an α of 0.35 at the same frequency. You don’t get to add the alphas together. Based on the total area of coverage, you must calculate the total sabins of each, then add those numbers together. For example: 128*0.60 = 76.8 sabins of absorption from material A, and 128*0.35 = 44.8 sabins from material B. Together, these add up to a total of 121.6 sabins of absorption at 500 Hz. Continue the same process if you have three or more different materials contributing absorption at the same frequency.

To help organize and crunch these numbers, I've created a Rough Order of Magnitude (ROM) sabins calculator. (Figure 14) This is a statistical calculator that requires T_{60} data from an existing (or modeled) room if you want to calculate before and after treatment results. For budgetary planning, it's a reasonably objective way to estimate the approximate square footage of each material needed to achieve your new T_{60} goals.

This sabins calculator spreadsheet file can be downloaded from the GraceNote Design Studio website[12]. General application instructions can be found by hovering your cursor over the *E3* cell labeled *Instructions*.

Note: The measured T_{60} data establishes the existing conditions in a room. The existing conditions are described as *Room Absorption*. Per IEC 801-31-11, Room Absorption (RA) is the sum of sabin absorption due to objects and surfaces in a room, and due to dissipation of sound energy in the medium (air) within the room."[4]

The spreadsheet automatically calculates - using Sabine's classical formula - the RA alpha values for each frequency when the known T_{60} times are input along row 23. The frequency-specific RA alphas are displayed along row 24.

Column F - from Rows 11-20 - is used to input and manipulate the total area needed for each treatment material considered. Recommended target T_{60} times are input along Row 26. The underlying formulas in Row 27 calculate the effects of the various treatment alphas based on the total square footage of each material applied at each frequency. The cells in row 27 turn green when you've found an exact match.

It's not necessary to perfectly match the times in rows 26 and 27, but they should come close. Try to stay within +/- 0.10 of a second. 4 kHz may be the hardest to match, but it's the most forgiving, so +/- 0.15 seconds or so should be close enough.

The Figure 15 chart displays all the key values shown in Figure 14, including the asymmetrical T_{60s} of this hypothetical, untreated room; the room's estimated, post-treatment T_{60s}; and the absorption coefficients for each of the materials selected to reach the target goals.

Don't forget, this is a ROM estimator. It's impossible to calculate and predict perfect results. This spreadsheet is simply a tool to help organize the data and streamline the numerous calculations, which are tedious to process.

GraceNote Design Studio

www.gracenoteds.com

Sabins Calculator

Client: PMAT

Room: Sample

Instructions	
Convert m^3 to ft^3	
Enter m^3 >	
ft^3 Result >	
Convert m^2 to ft^2	
Enter m^2 >	
ft^2 Result >	

Room Dims	
Length:	90.00
Width:	56.00
Height:	25.00
Volume (V):	126,000
Area (A):	17,380
Constant (k):	0.049

Index	Brand	Model	Mounting	Area	Absorption Coefficients						
A	GIK	T70	J	1,750	1.05	0.35	0.12	0.09	0.10	0.10	
B	Owens Corning	706 - 1" FG	A	600		0.01	0.22	0.67	0.97	1.05	1.06
C	MBI	4" Lapendary	J	24		1.31	1.11	1.14	1.17	1.15	1.19
D	KNC	Sereno 2/10 2"	A	750		0.38	1.19	0.66	0.31	0.19	0.12
E	KNC	Sereno 4 1"	A	450		0.24	0.64	0.61	0.43	0.29	0.21
F											
G											
H											
I											
J											

		63	125	250	500	1,000	2,000	4,000
Date > 05/20/25	Frequency - Hz >	63	125	250	500	1,000	2,000	4,000
	Enter Measured T60s >	1.86	1.47	1.64	1.49	1.31	1.26	1.19
	Calculated Room Absorption Coefficient >	0.191	0.242	0.217	0.238	0.271	0.282	0.299
	Enter Recommended Target T60 Times >	1.20	1.18	1.15	1.10	1.05	1.05	1.00
	Calculated Post-Treatment Times >	1.20	1.18	1.16	1.12	1.04	1.03	1.02

Slope Ratio		Model	Index	Total Sabins Per Treatment						
1.48	← Before	T70	A	1,837.50	612.50	210.00	157.50	175.00	175.00	
T60 SR6		706 - 1" FG	B		6.00	132.00	402.00	582.00	630.00	636.00
1.17	← After	4" Lapendary	C		31.44	26.64	27.36	28.08	27.60	28.56
500 Hz & 1 kHz		Sereno 2/10 2"	D		285.00	892.50	495.00	232.50	142.50	90.00
1.40	← Before	Sereno 4 1"	E		108.00	288.00	274.50	193.50	130.50	94.50
Mid-Band T60 Avg.			F							
1.08	← After		G							
500 Hz - 4 kHz			H							
1.31	← Before		I							
Speech Range T60 Avg.			J							

			63	125	250	500	1,000	2,000	4,000
1.05	← After	Frequency - Hz >	63	125	250	500	1,000	2,000	4,000
40	← Fs (Hz)	Pre-Treatment, Measured Sabins >	3,319.35	4,200.00	3,764.63	4,143.62	4,712.98	4,900.00	5,188.24
Schroeder Frequencies		Calculated Post-Treatment Sabins >	1,837.50	1,042.94	1,549.14	1,356.36	1,211.08	1,105.60	849.06
160	← 4Fs (Hz)	ROM Estimated Total Sabins >	5,156.85	5,242.94	5,313.77	5,499.98	5,924.06	6,005.60	6,037.30

Absorption Formula #1: A = (kV)/T60

A = Absorption in Sabins at a Given Frequency

V = Room Volume k = 0.049 T60 = Reverberation Time at a Given Frequency

Absorption Formula #2: A = α*S

A = Total Sabins of Absorption at a Given Frequency α = Absorption Coefficient S = Surface Area in Square Feet

Figure 14 – A statistical sabins calculator. Row 23 shows the measured T_{60s} for this hypothetical room. Row 26 is where you enter the desired or recommended T_{60} values. Row 27 shows the predicted results achieved using the acoustic treatments shown on rows 11-20. When cells turn green on row 27, the predicted values match exactly to the targeted values. Cell E3 contains a fly-off with more detailed instructions.

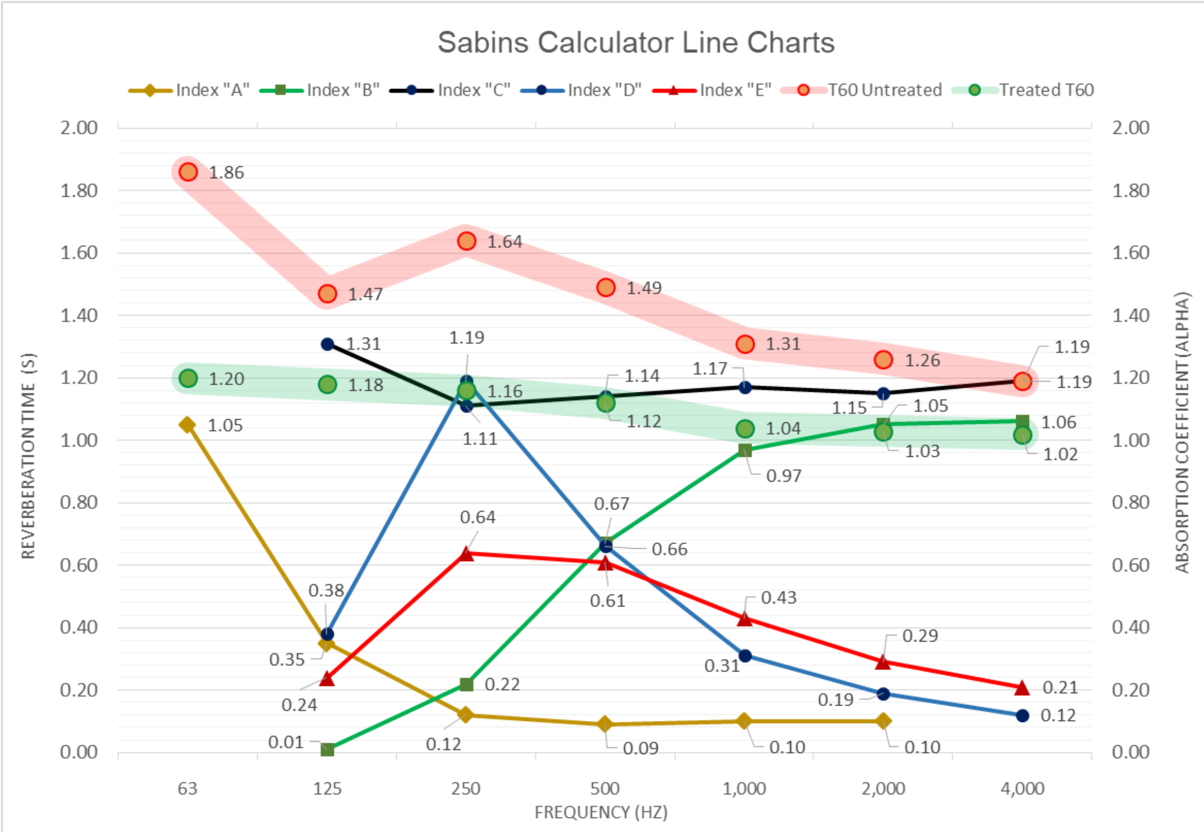

Figure 15 – From the Figure 14 sabins calculator above: A graphic representation of the before and after (broad red and green lines) T_{60s}. The thin lines show the absorption coefficients for each of the materials used to achieve this Optimal TSR grade.

More Examples with Varying T_{60} Profiles

Over the past thirty-five years or so we've seen Christian house of worship music shift dramatically - from the traditional/classical genre with mostly acoustic instrumentation, to today's worship music that's contemporary, rhythmic, and often quite loud. However, in many instances, these sound-critical environments have not been adjusted accordingly, if at all.

Below are three examples of how PMAT solutions might be or have been applied in such venues. The first (Figure 16) represents a hypothetical, yet somewhat ubiquitous, highly reverberant church sanctuary. The T_{mid} is 1.80 seconds, which rises to 2.42 second T_{60} at 63 Hz. Untreated, this example gets a *Fair* TSR grade based on its score of 1.45. A venue such as this may have been wonderful for mass choir, pipe organ, and/or orchestra, but it's not acoustically *friendly* for modern-day amplified music, nor spoken word intelligibility.

Suppose this hypothetical church wants to modernize their worship music programming. What will their acoustic challenges be? It isn't too difficult to reduce the overall mid- and high-frequency T_{60s}, but to bring the TSR up to at least a *Good* grade, the 63 Hz and 125 Hz octaves must also be addressed.

Currently, no known single product can provide every adjustment that may be appropriate for this example. As many as four PMAT filters may be needed.

Hypothetical Example - Room 1

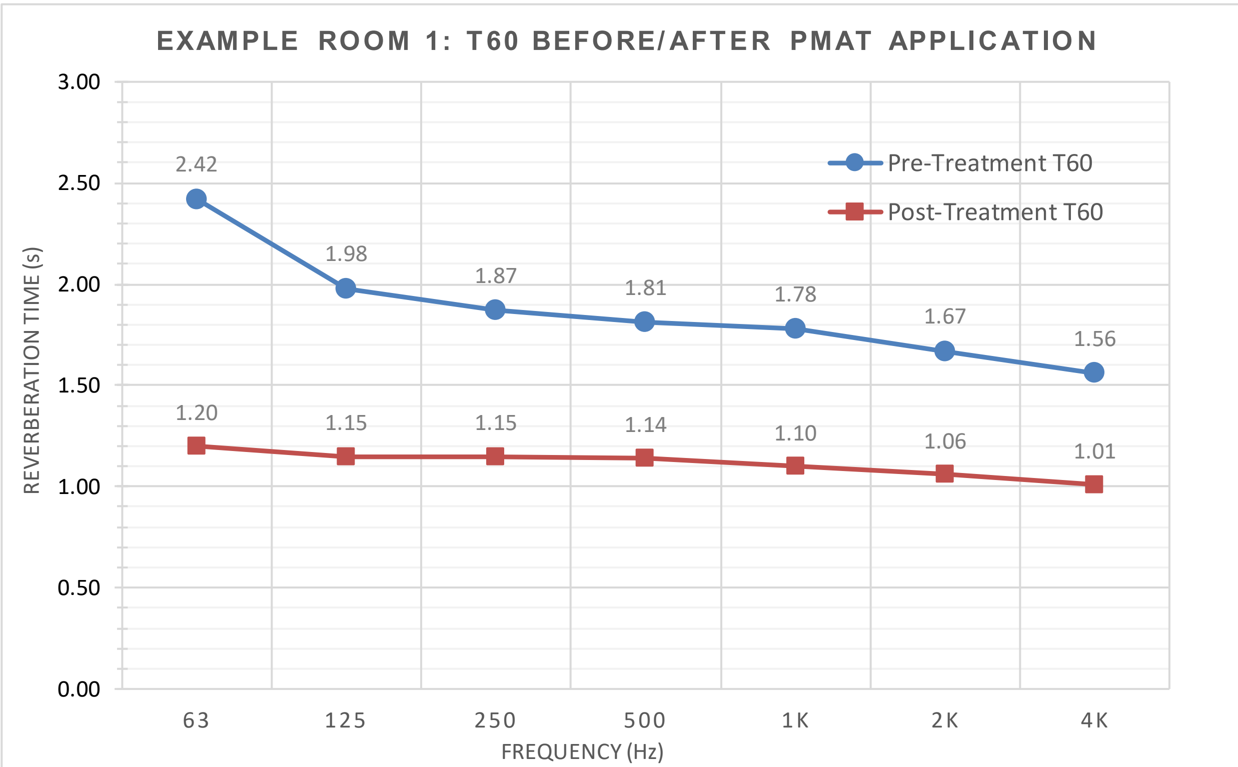

Figure 16 – Representative before/after line charts for this sound-critical room, which has too much overall reverberation for good speech intelligibility and rhythmic music clarity.

Because it will drive all other acoustical decisions, setting the new goals for a room like this should begin with the T_{mid} conversation. If, because of genre or budget, the goals need to change to either a longer or shorter T_{mid}, only the quantity of each material needs adjusting.

For this 177,000 ft^3 (≈ 5,000 m^3) room the basic post-treatment goals might be as follows: T_{mid} target – roughly 1.10 to 1.15 seconds; 125 Hz T_{60} target - 1.15 seconds; and an Optimal TSR grade. Figures 17 and 18 below show examples of how this PMAT solution was calculated.

We now have the guidelines and tools needed to estimate and specify appropriate materials for a room like this. Of course, the placement of each material requires careful analysis and execution, as well as customer approval.

Hopefully, the way all these metrics work together is beginning to make sense. They attempt to define, shape, and deliver the best possible acoustical characteristics in a room.

Potential Solution for Room 1

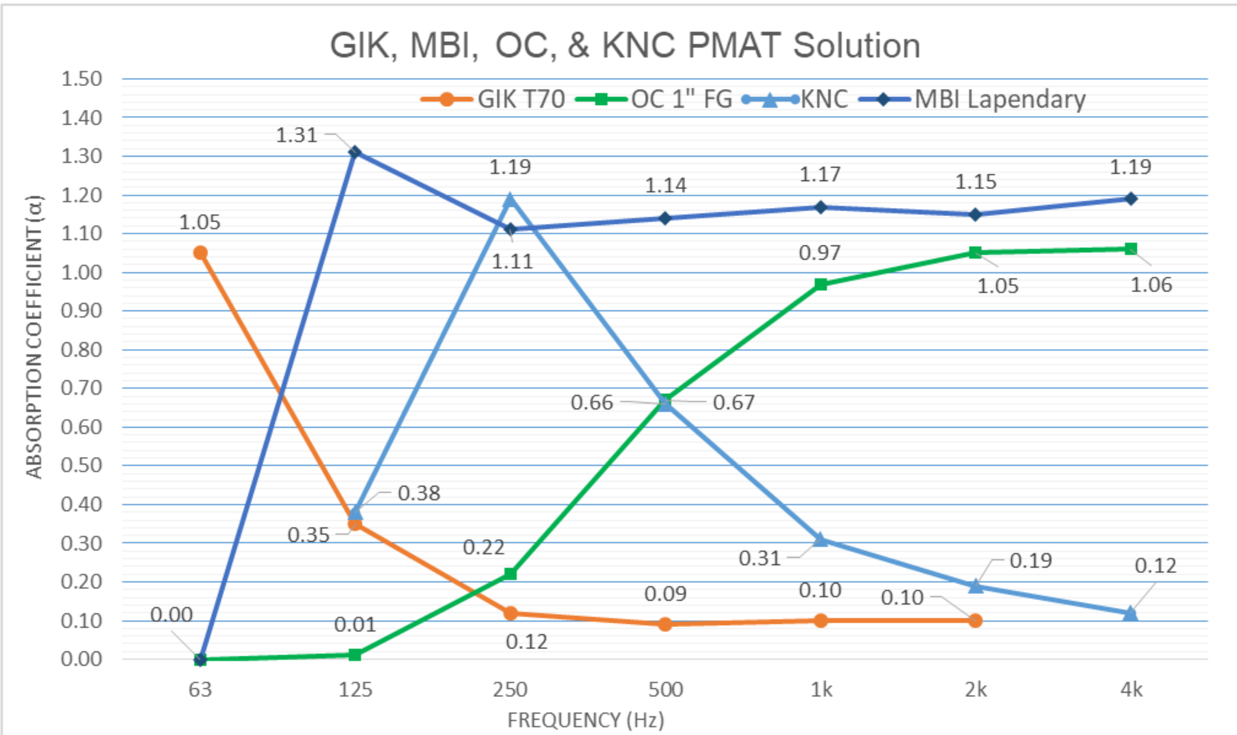

Figure 17 – Using a combination of these four products should be effective in taming the T_{mid} in this room, while also hitting the 125 Hz target, and delivering an Optimal TSR grade.

10	Index	Brand	Model	Mounting	Area	Absorption Coefficients						
11	A	GIK	T70		3,500	1.05	0.35	0.12	0.09	0.10	0.10	0.10
12	B	MBI	4" Lapendary		1,250		1.31	1.11	1.14	1.17	1.15	1.19
13	C	OC	6 PCF		1,000		0.01	0.22	0.60	0.97	1.05	1.06
14	D	KNC	Serento 2/10 2"		750		0.38	1.19	0.66	0.31	0.19	0.12
15	E											
16	F											
17	G											
18	H											
19	I											
20	J											
21		Date >	04/20/21	Frequency - Hz >		63	125	250	500	1,000	2,000	4,000
23		Enter Measured T60s >				2.42	1.98	1.87	1.81	1.78	1.67	1.56
24		Calculated Room Absorption Coefficient >				0.176	0.215	0.227	0.235	0.239	0.255	0.273
26		Enter Recommended Target T60 Times >				1.20	1.15	1.15	1.10	1.10	1.10	1.00
27		Calculated Post-Treatment Times >				1.20	1.15	1.15	1.14	1.10	1.06	1.01

Figure 18 – The sabins calculator (Figure 14) provides a convenient way to estimated and evaluate how much of each material is needed. This analysis also suggests that at 63 Hz, using a more effective diaphragmatic absorber may be beneficial to reduce the required square footage.

Example Room 2 – 25-Year-Old Presbyterian Church

Example Room 2 is a work in progress. This example is based on an architecturally-challenging, 99,100 ft^3 (≈ 2,800 m^3) sanctuary, located near Irvine, CA.

This is a real-world example of how PMAT works in the planning stages of a project. Final test results will not be available anytime soon, so only estimated results are shown. The results are based on my recommended solutions, which were plugged into the sabins calculator.

The church has modernized their worship music, which can now be described as *light* contemporary. Acoustically, their main complaint is *boomy and muddy sound*. These comments aren't too hard to imagine after looking at the *Pre-Treatment* RIR measurements shown in Figure 19. The room's current T_{mid} is 1.43 seconds. Ironically, the current TSR score is also 1.43, which is gets *Fair* grade.

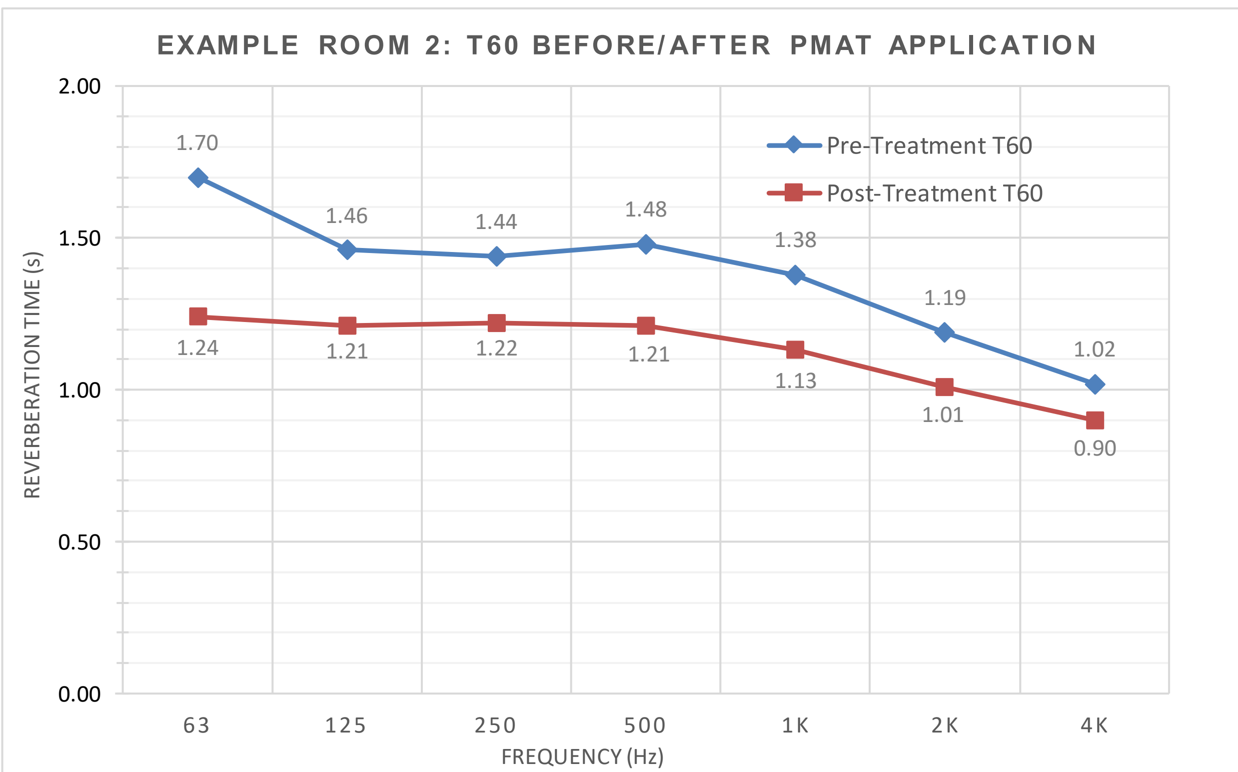

Figure 19: The sound in this sanctuary is described as *boomy* and *muddy*. The pre-treatment chart confirms those comments. The goal is to *minimize* the absorption of 2k and 4k energy, while reducing the T_{60} of everything below to the new target levels. Also, note the asymmetrical shape of the *before* slope.

Moving forward, their goal is to lower and smooth out the room's reverb and resonance profile, so it falls within at least the *Good* TSR range. Their new T_{mid} target is 1.25 seconds, or a little less if possible. Based on the *Post-Treatment* predictions, those goals should be achievable.

The treatment solutions shown in Figure 20 consist of: 200 ft^2 of the Mega Trap product, 850 ft^2 of the Modex Corner 62 product, 100 ft^2 of 2" Bandit product, and 500 ft^2 of fabric-wrapped, 1" fiberglass paneling.

Interesting note: As mentioned earlier, the architectural structure of this room is very challenging. It has a fan-shaped pew seating footprint (with curved pews), which is placed in a + (plus) shaped structure, with radically-varying, non-symmetrical ceiling heights.

Ordinarily, the 1" fiberglass paneling would not be specified for this project because it does too much work between 1k and 4k. But, because of the awkward (and only reasonable option) point-source loudspeaker positions, something needs to be installed to minimize the slap echo off the hard, parallel, vaulted-ceiling surfaces that the loudspeakers must fire under (long story). Diffusion panels would be a better option, but cost, aesthetics and weight considerations rule out that preference.

Proposed Solution 2

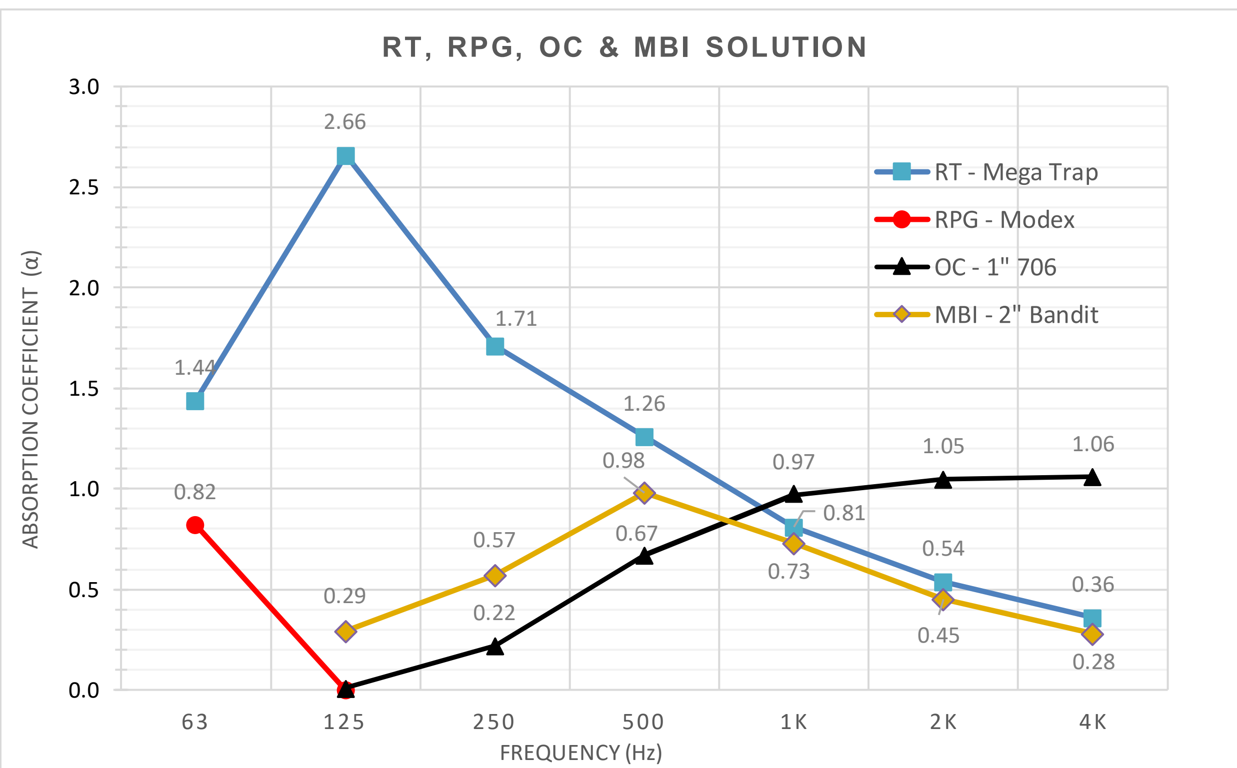

Figure 20: This combination of treatments should deliver something close to the Post-Treatment T_{60} results shown in Figure 19.

Example Room 3 – Saddleback Church

Saddleback Church, in Lake Forrest, CA, serves as a real-world example of the applied PMAT process. Because of their loud, contemporary style of worship, the church representatives expressed a specific appeal to not only reduce the overall reverberation in their worship center by about one second, but also include a custom solution to address the excess VLF and LF resonance and reverb as much as possible.

The Saddleback Worship Center is quite large, seating just under 3,000. The room volume is roughly 1,084,500 ft^3 (≈31,000 m^3), with lots of highly reflective glass and steel. The Schroeder frequency is 17 Hz, and when the $4F_S$ multiple is applied it shows the room is sufficiently large to develop true reverberation down to 68 Hz. This means everything that seems like reverb, below 68 Hz, is most likely modal resonance.

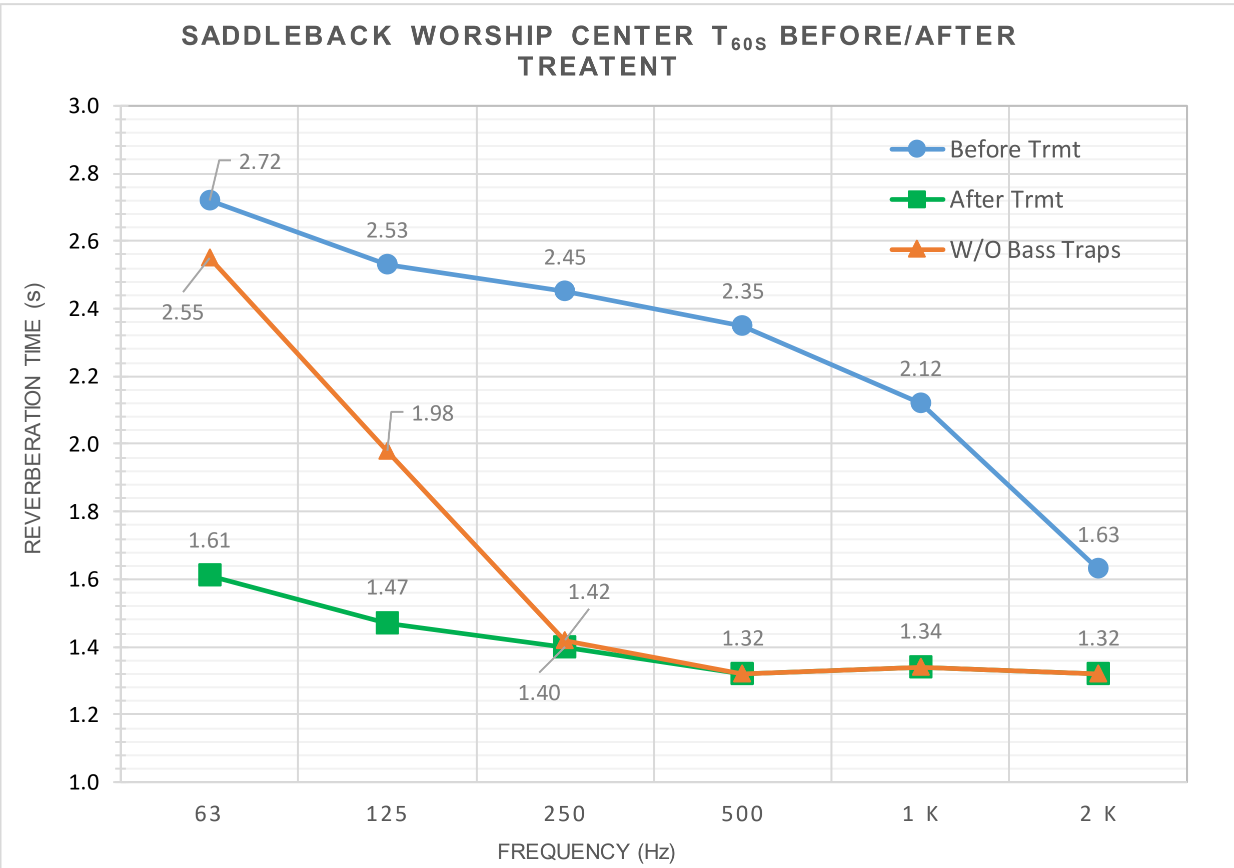

Figure 21 shows the before and after RIR results at Saddleback Church. Had only the hanging baffles and batt insulation described below been installed, the sabins calculator shows that the 63 and 125 Hz bands would still have way too much reverberation and modal energy for their contemporary worship music.

To accomplish this, it took a little more than 12,000 ft^2 of hanging 2” fiberglass (6 PCF) baffles; over 7,000 ft^2 of hanging 2” cotton (3 PCF) baffles; and about 2,700 ft^2 of R-30 batt insulation.

To mitigate the excess VLF/LF energy, 20 huge (98 ft^3 ea.), custom-designed bass trap resonators were deployed. Based on our shop testing, these resonators would provide an average attenuation of 8 dB within the frequency range of 50 Hz to 100 Hz. Acoustically, 8 dB is very significant. To review, 6 dB of attenuation is one quarter of the original power. The peak frequency of attenuation appeared at 75 Hz (-18 dB), and the weakest came in at 53 Hz (-4 dB).

On site, pairs of the custom resonators were grouped and positioned near floor/wall boundaries in each of ten antinode pressure zones. Each zone was pre-identified and aesthetically approved by the owner. The antinodes were identified in situ using a 63 Hz sine wave signal and the house-system subs.

Finding appropriate locations to install all these treatments was challenging. No wall attachments were allowed. The single largest area available was the ceiling. There, edge-hung baffles could be installed just below the corrugated-steel roof deck, delivering 64 ft^2 of absorption from each 4'x8' panel. A case study report on this project can be found here.[13]

There’s little doubt that the 2” baffles helped somewhat at 63 Hz and 125 Hz, but all those 6 PCF baffles have the same absorption profile as the 2” Owens Corning panels shown in Figure 2. Figure 21 reveals that, by themselves, the hanging panels would not provide all the LF and VLF control that was desired.

Here’s an example of how location and mounting techniques can make a tangible difference: At the back of the room there is a large area where low- and low-mid energy (125 Hz – 250 Hz) would build up below the retractable stadium seating. This is where most of the cotton baffles were hung – draped over hangar rods - soaking up much of the unwanted low-end reverb where it developed. None of this treatment was visible to the public.

While most of the absorption work was accomplished with these products, a new line array loudspeaker system – with cardioid subs – also helped reduce the indirect energy being pumped into the room.

Pivotal elements that influenced winning the contract for this project were our clear understanding of the customer’s overall acoustic problems, the proactive design processes used to address their structural and aesthetic limitations, and a commitment to resolve most of their low-frequency challenges.

What about Variable Acoustics?

Is all this necessary if you have, or are planning for variable acoustics? The short answer is: probably. Some electro-acoustically controlled VA schemes are additive - adding reverb to a room that's too *dry* for the audio content being presented. Examples are systems like the Meyer Constellation, the E-Coustic Systems Gen 3, and the Muller-BBM Vivace.

Some are subtractive - absorbing, or cancelling, reverb and resonance. Examples are the Flex Acoustics Evoke and aQflex systems, or the Bag End E-trap.

The earliest VA schemes were manual systems that required opening and closing drapes, rotating adjustable absorptive/reflective panels, or opening/closing auxiliary reverberant chambers. These methods all had/have limitations based on how much variation they can provide, and in the frequency bands they can address.

For all practical reasons, deploying a VA system is pretty much a one-way street; you can either add or subtract reverberant energy. But, you can't subtract energy using an additive system, nor add energy using a subtractive system. Each scheme has limits to what can and can't be controlled. Therefore, the primary question becomes: What is a room's tonal character (its T_{mid} and TSR grade) before any VA scheme is installed?

Remember, all VA systems must start with the baseline acoustical profile a room provides. From there they attempt to add or subtract reverberant energy in the most efficient way possible; given the range of variables available within the system's design.

This is why initially starting with the best possible and most appropriate T_{mid} and TSR grade should be the goal for any room slated for a VA system.

Final Thoughts

When my career in pro audio and acoustics began, I never expected to find myself so focused on the nuances of large room acoustics. Over the years, a prime tenet has been to look for the weakest links in my audio and acoustic toolboxes, then work to strengthen those weaknesses as much as possible so that other things become my current weak links.

With that mindset, I've long believed the weakest link in architectural acoustics is a lack of interest and attention paid, by too many practitioners, to embrace, identify, and treat excess resonant and reverberant energy – at and below 125 Hz. Moreover, many acoustical product manufacturers, and reference books on the subject, fail to address this aspect adequately.

For sound-critical venues focused on modern amplified music and production, acoustic standards and specifications should aim to meet suitable T_{mid} and 125 Hz targets. Additionally, implementing customized PMAT solutions can help achieve a Good to Optimal TSR grade, thus enhancing the acoustical qualities of the built environment.

Some may argue that applying the PMAT approach is too much trouble, or too expensive. The same was probably said about Dr. Peter D'Antonio's QRD diffusor systems back in the early 1980s. But today, diffusors of various types and sizes are commonly specified and installed.

It is suggested here that when implementing the Parametric Method of Acoustic Treatment, the outcomes will validate any minimal additional effort and investment required.

Change will no doubt come slowly. It may take years to see common usage of the PMAT techniques. Hopefully, this new perspective will spark industry awareness, and help launch this topic into the mainstream of architectural acoustic solutions.

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14 - https://tinyurl.com/AE4A-jrp; https://tinyurl.com/AE4A-amazon; https://tinyurl.com/AE4A-bn; https://tinyurl.com/AE4A-vital

Peer Review Panel

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