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This month: *How do you measure thy sound? Let me count the ways…*

**Theory and Background Discussion**

There are many ways to measure room acoustics. Some are good. Some are not so good. Before we get too deep into the different methods – indeed, before we even start to measure anything – we need to answer a few basic questions:

1. What is it I wish to measure?
2. What is the expected result of the measurement?

If the answer to question 1 is, "I want to measure how my room sounds," then we can stop right there. We can measure a lot of things. Actually correlating a bunch of dots on a page to a subjective evaluation such as "how a room sounds" is impossible. Besides, if this is the answer to question 1, then the answer to question 2 would no doubt be, "I expect my room to be excellent." There are no measurement, testing or analysis tools that have a "suck" to "rock" scale. (Sadly.)

So what do we do? Let's talk about what we would like to figure out:

- We would like to know if what we're hearing is accurate.
- We would like to know if accurate translates somehow to "my room rocks."

This *Acoustology* is only going to cover the former – and should only be perceived as the very briefest of overviews. As far as what you are actually striving for in subjective terms, we leave that up to you.

But it is important to try to answer the "accurate" question before we get started. For example, you might find that you measure your room and there are peaks and dips all over the frequency response. Yet, you find that your mixes translate and you've never heard a single problem. If so, then you can probably close this document and get back to mixing. You won't need to be doing any measurement.

You might also measure the room, see that it's fairly smooth in terms of frequency response, yet you know your mixes aren't translating and you can hear all sorts of strangeness in the room. You will want to read on…

Finally, most of you are probably reading this just trying to figure out whether you need to measure at all. For you, I have prepared the following list of questions:

1. Do you find that your mixes do not translate, even though you've put up what you believe is a generous helping of acoustical treatments?
2. Are you comfortable using hardware and/or software with which you might not be familiar? Even if said hardware/software has a (sometimes) steep learning curve?
3. Can you afford to buy or rent some modest test gear – hardware and software?
4. Do you have (at least) a few hours to setup the equipment, perform the measurements, document the results and prepare them for review by others?

If you answered yes to all of the above, let's get started. (Note: If you only answered **No** to question 4, then you might consider hiring a pro to assist you. Of course, that will elicit a fifth question: Do you have the funds to hire someone to help you?...)

To thoroughly measure room acoustics, you will need results that show you the time, space and frequency responses of the room:


- Time response: How does sound decay in the room?
- Spatial response: How does sound behave at different locations in the room?
- Frequency response: How does sound behave at different frequencies in the room?

The above are all interrelated:

- Time response: Different frequencies decay at different rates. Different locations will yield different decay properties.
- Spatial response: Different locations will yield different decay properties. Frequency behavior will vary (sometimes greatly) at different locations in the room.
- Frequency response: Different frequencies decay at different rates. Frequency behavior will vary (sometimes greatly) at different locations in the room.

Or more simply:

*What is the decay of a frequency (or range of frequencies) at different locations in the room?*

If we can answer this, we will have gotten quite close to correlating the objective to the subjective as possible. In other words, for a room to sound "good," we will want to have all the frequencies behaving similarly over time at all locations in the room. To do this, we will need:

- Minimal early reflections because early reflections will change the frequency behavior at the mix location. This change could skew imaging or otherwise causes mixes to not translate out of the room.
- Minimal low frequency problems because they cause unwanted build-ups and cancellations at the mix location that will make our mixes not translate out of the room.
- Minimal decay since that would be synonymous with reverberation. Room reverberation could affect the choices made when adding certain effects to a mix.

In the next section, I review the most common measurement systems currently available. With all of them, you will want to playback the test signal through your loudspeaker (one is preferred to running the signal through both loudspeakers in a 2-channel setup) and place the measurement microphone at many different locations in the room. Around the mix position should be the most obvious area. But you should also measure at other locations in the room, if for no other reason than to get a "big picture" of the loudspeaker/room interface. (All the same concepts apply to measuring rooms other than control rooms as well.)

You will want to set up the measurement system such that you are getting good low frequency and good high frequency information. This will not be easy. There is a trade-off in many measurement systems whereby you will usually not be able to get all this information from one measurement. This is also another good reason to measure at many locations in the room.

In the future, I hope to have the time to put together "step-by-step" instructions for each of the systems below. As it stands, the manufacturers of each of the systems below actually have great resources of their own for this. Thus, if you are seriously considering testing and measurement, you should spend some time on their websites and learn as much as you can.

**Test Systems and Techniques**

What not to do: The most common "test results" we receive from folks usually go like this:

Someone takes a test CD (with tones or noise signals on it) and plays it through their system while measuring the sound pressure level (SPL) using a sound level meter (SLM) or a Real-time Analyzer (RTA). While this is likely to show "dips" and "peaks" – particularly at the low end of the frequency spectrum – it does not necessarily mean that those are the problem frequencies of the room; mainly because other extraneous noise, system response and human

error have been included in the measurement. Even the relative positions of microphones and loudspeakers can affect the response – something that will change as you (or your microphone) move around the room.

Also, it is worth noting that the resolution of something like an RTA is typically far too coarse to tell us anything about the loudspeaker/room behavior. Typical RTAs have – at best – ⅓-octave resolution. Looking for low frequency problems on a ⅓-octave RTA display is like looking for the street you live on using a globe.

From time to time we also have folks send us the results of Reverberation Time ("RT," "RT60," or "T60") measurements and/or predictions of their room(s). Unfortunately, RT60 is a measurement intended for a large, statistically reverberant space. A good example of this type of room would be a gymnasium. So unless the room is larger than about 25,000 ft³, the RT60s really don't tell you much.

Now that we know what *not* to do, we'll talk about good measurement techniques. To get that started (finally!), I have prepared a list of equipment you should look into purchasing or renting in order to get the best possible results:

1. Microphone. The preference here would be for a high-quality, omnidirectional microphone with a flat frequency response over the test range (usually 20 to 20,000 Hz). Good omni microphones – some specifically made for testing – are available from most microphone manufacturers. A cardioid (or other polar pattern) can be used, but an omni microphone specifically designed to have a flat response for testing will yield the best results. (Most recently, *Behringer* has come out with their *ECM8000*, a very affordable test microphone – usually under $50.00. If your intention is to only ever measure a small handful of rooms, it might be a good investment.)
2. Microphone preamplifier. Again, this is something that should be specifically designed for testing. (This is one of those cases where tubes probably aren't desirable.) The best bet is to check with the test microphone manufacturer to find out the best preamp they recommend using with their mic. [Note that some measurement platforms (see below) come with built-in microphones and/or microphone preamps.]
3. Sound source/amplifier. You might think this one is easy – your loudspeaker(s) or amp/loudspeaker system. True, to a degree. It depends on what properties of the room you would like to investigate. To just figure out everything the room is doing, you should use an omnidirectional "point" source with a flat, "reference" amplifier. (Since the signal levels for small room measurements are likely to be relatively low, amp size should not be a big concern.) In the loudspeaker world, the only thing that comes close to a point source is a dodecahedron loudspeaker. (A "dodec.") This is a "ball" of loudspeakers – 12 in all – that looks like this:

   The catch is that dodecs are expensive to buy and complicated to build. Thus, using the loudspeakers you have at your disposal is probably the best way to go. Unless, of course, your measurement platform (see below) does not require a loudspeaker for a sound source. If all you need to do is generate an impulse-response, you can use a balloon, a "clicker," a cap gun, or even your own two hands. The broadband nature of any/all of these types of sources will vary.
4. Measurement platform. A measurement platform consists of hardware and software that will:
   a. Generate test signals through a loudspeaker or amp/loudspeaker source.
   b. Acquire and correctly interpret the measurement information (the "data") from the incoming microphone signal.
   c. Possibly provide tools with which to analyze the data after they've been collected.

There are quite a number of hardware/software platforms available. Some are stand-alone units and some are designed to interface via a PC or MAC. The platform can be the single most expensive part of the measurement process. However, at least one software package is designed to be affordable with regards to room measurement. Here is a list of platforms starting from the least expensive and working up:

- A program called *ETF 5.x* from AcoustiSoft is available for right around $200.00 from. This program uses an MLS or swept sine signal generated via your PC's soundcard. Detailed setup and help files are included with the program. *AcoustiSoft* also offers a microphone/preamp package designed for use with *ETF* – though using your own is fine. (*AcoustiSoft* maintains that the PC soundcard is actually fine to use. Simply connect up the external hardware as described in *ETF's* very useful Help files.)

- A stand-alone unit (no computer required, though PC and MAC interface software is available via on-board MIDI I/O) called the *Audio Toolbox* (ATB) is available from TerraSonde. The ATB certainly offers the most bang for the buck in terms of tools available. (Systems vary by choice of hardware and firmware. In general, you can look to spend as little as $1,400.00 and as much as $4,000.00 on a good ATB system. This is extremely affordable based on the myriad features the ATB can offer – outlined below.)

  Besides room measurement capability via an RT60 (large room) and ETG (small or large room) module, the current Contractor's version of the software also boasts a sound level meter, an RTA, a single-channel, narrowband FFT, RASTI measurement, sound study measurement (environmental noise), a signal generator, a cable tester, and so on. There are inputs and outputs of all manner built into the box. The display is a backlit LCD. The *ATB-Plus* comes in a case with its own microphone, windscreen, stand clamp and cables and boasts a durable aluminum chassis. It also comes equipped with a removable, rechargeable battery and AC power capability. The *ATB-3* will be shipping soon and will offer quite a bit more capability than the *ATB-Plus*, including dual-channel, *Grace Designs* microphone preamps, a faster DSP, USB-Pre capability, a better battery, a lower-power backlit display and even more firmware goodies. In all, the *ATB* is a must have if you ever plan on measuring *anything* in your studio – even beyond the room acoustics. I highly recommend it.

- *SMAART AcousticTools* from SIA uses FFT analyses of impulse response measurements to provide information about a room/system. The software is reasonably priced (under $1,000.00), works on PCs and – like *ETF* – requires your own outboard measurement gear (mic and source). *SMAART* offers quite a lot for the price and is quite useful for post-analysis of test signals recorded on site. (See below.)

- You may have heard the phrase "TEFfing the room." What this refers to is a system from Goldline called *TEF*. *TEF* uses what is called "Time Delay Spectrometry" (TDS) to generate and analyze measurement signals. Here are the components:

  - The *TEF20SHIP* is the *TEF* unit itself. This is connected to and controlled by a PC.
  - The software interface is windows-based and connection from PC to *TEF* is via parallel port or USB.
  - The *TEF* has built-in microphone preamps (2 balanced, phantom-powered XLR) as well as line inputs (2 BNC) and a line level (BNC) signal output.

  *TEF* is really designed for the higher-end user. Consultants and designers are quite fond of it. The system, plus the software modules will likely cost you in excess of $4,000.00. Thus, *TEF* is not really designed for the lay, one-time user. However, it can be used to test just about anything with regards to acoustics. Certainly a great investment if you're looking for something like this.

I have run and compared measurements from all of the above systems, using as much consistency between equipment as the platforms allow. Measurements done at identical mic and loudspeaker locations yielded results that all agreed very well with each other. Thus, you can pretty much base your decision on what you have to spend, what you would like the measurement system to do (e.g., outside of room acoustics in the case of the *Audio Toolbox*), and how often you think you will be testing and measuring your room.

It is worth noting that – by using *SMAART*, *TEF* or *ATB*, *Auralex* is able to perform reasonable off-site room analyses. Using *Sound Forge's Acoustic Mirror* plug-in, an *Auralex* analyst is able to process a swept sine recorded in your room to extract your room's impulse response. *SMAART* (or other platforms) can then be used to perform analyses from right here in our office. There is a charge for this type of service and it does require more than just a single room measurement. Contact us for more information.

Also, *Auralex* is able to work with *ETF*, *ATB*, *SMAART (AcousticTools)*, or *TEF* files of any type. Should you already have information about your room in any of these formats, feel free it to forward to us for review. Or, if you would like to know what you can do with any of these platforms, please feel free to contact us.

**Concluding Thoughts**

To summarize, before you measure, ask yourself these questions:

1. Have I listened to the room?
2. What did my listening evaluation tell me?
3. What am I measuring?
4. Why am I measuring it?
5. What should the measurement tell me that I don't already know?

And note that you may not have all the answers yet. The first question, though, is the single most important. If you can't hear any problems, there's nothing to fix. Hence, there's nothing to measure.

Finally, if you are really serious about getting the room right in terms of acoustics, hire someone. We have great relationships with many, many experts in audio and room acoustics across the country. Feel free to contact us to find out if we know someone near you!

(I would like to include a special note of heartfelt thanks to my good friend and colleague, Doug Jones, Chair of the *Audio Arts and Acoustics Department* at *Columbia College* in Chicago. Doug graciously shared some wonderful insight with me for this issue of *Acoustology*.)

Next month: *Pontifications on Diffusion…*