

## Tuning A System With FFT

Techniques for getting it really close

By John Murray

**W**hen last we left off, you had just acquired a 3-D, FFT-based measurement system and were ready to use it to tune a sound system. (*Tech Talk, June 2004 issue*) So let's get to it!

The first thing to do is place the calibrated measurement microphone on a mic stand in the middle of the listening area, turn on all of the system's

loudspeakers and turn up the test signal, just as is done with a Real-Time Analyzer (RTA). Right?

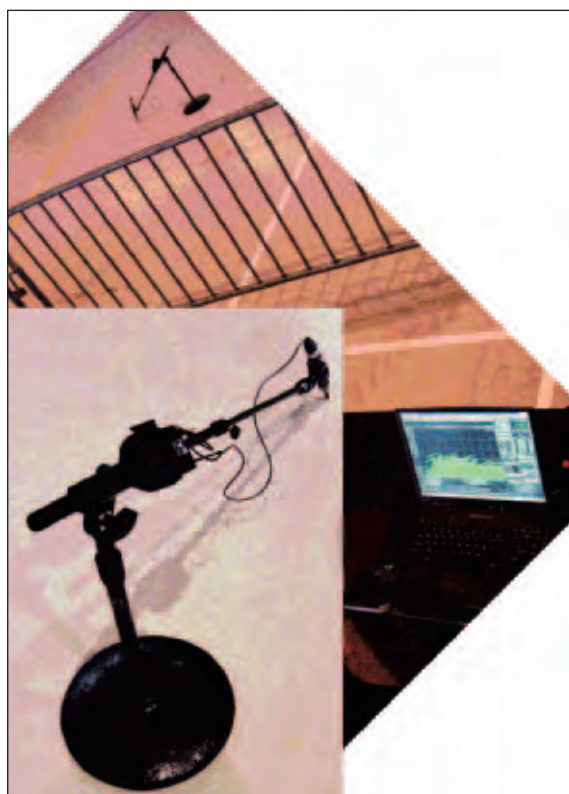
Sorry – wrong!

First, putting the mic on a common mic stand can unnecessarily contaminate the FFT (Fast Fourier Transform) measurement. That hard reflection off the floor is a non-minimum-phase, delayed source whose effect cannot be equalized.

When making (SIA) SMAART and (Meyer Sound) SIM measurements, the mic should be laid in a pressure zone (PZM) position directly on the floor. This will remove the comb-filtering effects of the reflection from the measurement.

If using (Gold-Line) TEF, it's acceptable to put the mic on a light stand to get it away from the floor so that the reflection is delayed enough to be "windowed" out of the measurement time limits. Low-frequency response of the measurement will also be limited, but room modes render low-frequency measurements within a room and far from the loudspeaker(s) useless anyway. (More on this later.)

Be aware that any hard, reflective surfaces near loudspeakers will also cause the same types of problems. Either move and aim the loudspeakers to avoid creating these reflections, or treat the surface with absorption to prevent them. Otherwise, a comb filter (**Figure 1**, next page) will color the source's tonal quality for most listening posi-



*Start the process off right with proper measurement mic positioning!*

tions for a given loudspeaker in a system.

Because 3-D measurements are time-sensitive, other loudspeakers can cause comb-filter contamination just like reflections. Therefore, they must be eliminated from the measurement. (See **Figure 1** again!)

That's right, you need to be equalizing for a flat, direct response on-axis to just one loudspeaker per crossover-bandpass section. Where long wavelengths combine, such as with subwoofers and the low-end of the low-mid loudspeaker frequencies, further consideration is needed.

And for mid-highs, this is a hard and fast rule. Any other frequency response problems – such as lack of high-frequency level at listening positions off-axis or between cabinets – are issues of inadequate coverage, not equalization.

Because we're equalizing loudspeakers and not rooms, particularly at short wavelengths, separate EQ is needed for each type of loudspeaker. One equalizer cannot be tuned correctly if it's feeding multiple types of loudspeakers. Again, dedicated EQ and amplifier signal path for each type of loudspeaker is required.

For example, take a loudspeaker cabinet loaded with double 12-inch or 15-inch woofers. The measurement mic – during EQ – must be positioned exactly between the two drivers, so that the path-length from each are close enough to not have any cancellations at the frequencies that the drivers are reproducing.

However, if a cabinet has two tweeters reproducing the same frequencies, the mic cannot be placed accurately enough to prevent cancellations at very short wavelengths, so proper equalization is not possible. Try permanently disconnecting one tweeter, because all listening positions will have high-frequency response problems due to this poorly designed loudspeaker.

Another concern is diffractive effects, particularly in the case of co-axial drivers. Due to the symmetric nature of most co-axial designs, diffractive effects can be emphasized.

This is why Frazier (a loudspeaker

manufacturer) takes great pains to add absorption to minimize diffractive effects for its co-axial systems. I recommend averaging several measurements across the coverage pattern of co-axial drivers and equalizing the average response.

Once the mid-highs have been equalized using one driver per pass-band – and without any strong reflections contaminating the measurements – then it's time to tackle the

lower frequencies.

#### IN A MODE

Room modes are summations and cancellations of long wavelengths whose dimensions are similar to the dimensions of the room. They cause additions that can be 12 dB or more where reflections sum, as well as cancellations of 20 dB to 30 dB deep where they're out of phase.

Rooms with regular dimensions

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that are multiples of each other, such as a 10-foot ceiling, 20-foot width and 80-foot depth present the strongest room mode effects.

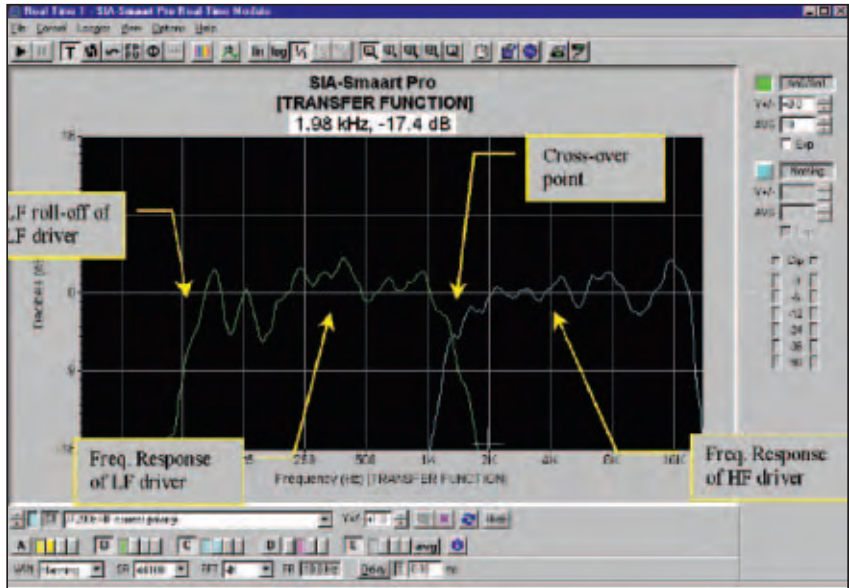
For example, generate a 100 Hz tone into a room with one loudspeaker. Then, walk the room and listen for hot spots and null points – they'll be 1/2 wavelength apart ( $1130/100 = 11.3/2 = 5.65$ -foot spacing). The most simply way to determine which frequencies are affected by room modes is to employ the simpler of two available equations:

$$R = (3 \times SS)/RSM$$

(R is the upper frequency limit of room modes; SS is the speed of sound; and RSM is the room's smallest dimension, usually ceiling height.)

So for a room with a 24-foot ceiling height (say, a high school gym), all frequencies below 141 Hz cannot be equalized with the measurement mic placed anywhere in the room.

Clearly, when there can easily be 30 dB variations in level around the room at a given bass frequency, those frequencies can't be equalized because the level is wildly position-



Frequency response of a two-way loudspeaker's high-frequency (HF) and low-frequency (LF) drivers as seen in the transfer function of SMAART. Note the roll-offs of the LF and HF drivers meet at -3 dB.

dependent. What to do?

Two choices:

- 1) EQ the bass tones with the loudspeaker system outdoors, such as in a parking lot with no reflective surfaces

nearby, and once again PZM the mic element against the blacktop for a ground plane measurement.

- 2) Use D.B. (Don) Keele's extreme near-field measurement technique described in a 1974 AES paper. This method places the measurement mic capsule about 1/8-inch away from the woofer's dust cap. For bass-reflex cabinets, the lowest 1/2-octave of response needs to be tuned with the mic in the port. (I've been using this technique for years with excellent results.)

Now that we've equalized both the mid-high and low frequencies – a process completely independent of the room – it's time to consider the acoustical environment's effect on equalization.

## BASS BUILD-UP

The only portion of a loudspeaker's response that a room influences is where fractional space loading occurs. This is in the long (low-end) wavelengths, where in-phase summation with nearby surfaces is an equalizable situation.

When a loudspeaker is against a floor, wall, or corner, the normally omni-directional bass energy sums in one direction and adds 6 dB (not 3 dB) for each doubling of surfaces (sources)

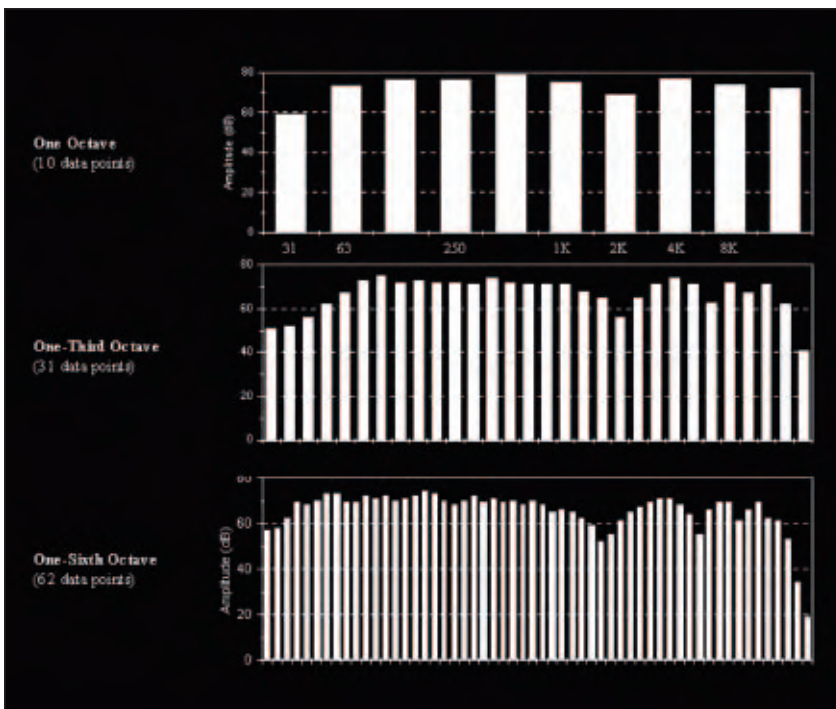


Figure 1: Resolutions of a comb-filter at various octaves.

at the longest wavelengths. This bass build-up is the one instance where "room EQ" actually exists.

Similarly, multiple low-frequency drivers act just like surfaces and add 6 dB per doubling of sources. This also must be accommodated in the final EQ curve.

However, because of room modes, the mic can't be placed out in the room where it will receive energy from all the surfaces and/or low-frequency drivers, because the bass response will still be wildly position dependent. The solution? The ear is still the best way to adjust the bass response. Listen from a few different positions to a variety of bass sources and you should quickly be able to determine a good low-frequency balance.

I generally adjust the drive (sub-crossover section or power-amp attenuators) to the system subwoofers in a three- or four-way sys-

tem by taking a gentle, relatively broadband approach to taming low-frequency build-up that changes very gradually with frequency.

Remember that air also has a very definite absorption characteristic for short high-frequency wavelengths. If the throw of a system is very long (hundreds of feet), consider a high-frequency EQ boost to counter those effects.

Keep in mind that this must be compromised between the closest and farthest listeners. Don't make it too bright for those up close.

Also, choosing a position far from the loudspeakers naturally leads to the expectation of less high-frequency content, so a flat response (to 15 kHz or so) might be disconcerting at 100 feet or more.

Finally, too much high-frequency boost can fry the drivers. Be careful!

#### VERY CONSISTENT

I've been using this methodology for

several years and have found it highly effective for tuning a system to within 95 percent of the final result, before listening to program source at all.

You'll also likely find it to work quite well, and keep in mind that it can be applied to any sound system. Sound will be natural and very consistent from system to system, regardless of room acoustics.

The sole exception is "boomy" rooms with very strong room modes. These situations require a system that doesn't excite the room modes, which can be removed from the system's response by using notch filters.

Happy tuning! ■

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*Live Sound Technical Editor John Murray is a 27-year industry veteran who has worked for several leading manufacturers. He has also presented two published AES papers, chaired four Syn-Aud-Con workshops, is a member of the TEF advisory committee and an ICIA adjunct faculty member. He can be reached at [jmurray@livesoundint.com](mailto:jmurray@livesoundint.com).*

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