The Physics of Music, Part 4

Putting acoustical theory into practice with a Sound Level Meter.

By Bill Markwick

In our previous articles on the physics of music, we covered sound pressure levels, sound intensity, loudness and other characteristics. This month, we look at making some practical measurements of sound using a calibrated meter. The results obtained should clarify some of the more confusing units that keep turning up in acoustics.

As mentioned before, sound pressures are measured by referring all readings to a starting point: the threshold of hearing, defined as 0.0002 microbars. Because the range of pressure from the threshold of hearing to the threshold of feeling is an enormous one, it's compressed into a more convenient form by using the decibel. The threshold of hearing becomes 0dB and sounds are compared to this by using the formula:

SPL = 20log(Pressure Ratio)

This decibel scale gives us a convenient means for measuring sound levels. Some typical values would be:

Quiet Recording Studio – 20dB
Average Residence – 45dB
Conversation – 65dB
Loud Orchestra – 90dB
Threshold of Feeling – 120dB
Loud Rock Music – 110
Jet at Takeoff – 130dB

These figures are approximate and vary quite a bit with the type of source, the distance, the measurement environment and so on, but they give a good idea of the range of numbers commonly used.

The Sound Level Meter

The SLM is a useful instrument for obtaining the above readings and for analyzing the sounds around us. Musical sounds, the acoustical environment and our subjective reactions combine to make the basics of sound appear to be far more complicated than they actually are. If we can make some proper measurements and obtain some valid numbers, it's much easier to break down a complex sound into simple parts. Mind you, I'm not saying that the study of sound can't get incredibly difficult, only that the basics are easier to grasp than people think.

The meter we used for the tests is the Realistic Sound Level Meter, avail-

A sharp way to empty an office in nothing flat. Besides the convenience, the tripod is used to prevent sound from reflecting from someone holding it.

able from Radio Shack, catalog number 33-2050. It can measure from 50dB to 126dB and has a frequency response of 32Hz to 10kHz using the flat response switch setting. This is more than adequate performance for general acoustical work, and at $36.95 it's quite a deal in test equipment.

The circuitry is straightforward. An electret condenser microphone feeds a single-transistor amplifier which is followed by a resistive attenuator switchable in 10dB steps. An IC drives the meter movement; two filters are provided, one for the response and one for the weighting.

The response filter is a large capacitor that's switched across the meter. This changes the meter characteristic from peak- reading to an average-reading type; the fast setting will react to sudden transients while the slow setting is better for measuring the average changes in ambient sound level.

The weighting filter has two settings, A and C. The frequency response of the C setting is flat (within the limits of the microphone); there is no emphasis or de-emphasis of any particular frequency. The A weighting switches in a filter that cuts the low frequencies starting at 500Hz; there is also a slight boost to the higher frequencies starting at 2kHz. The reason for this is to tailor the meter's response to approximate that of the human ear; as we pointed out in past issues, the ear is not as sensitive in the bass regions as it is in the midranges.

We also pointed out that the ear's frequency response changes with loudness: lots of bass and treble is required at low listening levels. For this reason some sound level meters have another filter, the B type, switched in for sound levels above 60dB or so. However, the A weighting is what everybody uses for approximating the ear's response under most condtions and it's all that you'll need.

On the side of the meter is a phono jack output for connecting to oscilloscopes, recorders, etc., and on the bottom is a standard tripod socket. Tripod mounting is recommended for best accuracy, since holding the meter may cause errors from sound reflected from the body.

Level Checks

The first thing we did was check the ambient noise in the office early one quiet morning. With the C rating, it tended to be about 55dB and very jittery. The oscilloscope revealed that the jitters were from people in other parts of the office rustling bits of paper, dropping pencils on desks, etc. Those are the sorts of sounds you automatically tune out once they become familiar, and it's a strange feeling to have the meter reveal them for you once again.

As more people came in and more conversations (and machines) were started up, the level gradually rose, requiring a 10dB move upward in the sensitivity setting, which eliminated the now- buried jitters.

The next check was to measure some musical instruments in a quiet room. I used the C weighting amd mounted the meter on a tripod one metre away (the usual distance for level checks).

Trumpet

The trumpet is as loud as you'd expect: its lowest note (C) measured 90dB with no straining at all. As any trumpet player could predict, the level went up as I went up the scale. The next G, which is the next step in the natural harmonic series, registered 100dB and the octave C 105db. Then the level began to fall off with the higher notes, partly due to my poorly trained lip and partly due to the trumpet's inherent limitations in the treble end of things.

A cup mute reduced the above readings by 5dB, though to the ear it sounded like much more, perhaps because the high frequencies are attenuated more, like turning down the treble control.

In a future issue, we'll be examining the physics of resonant tubes using the trumpet as an example, and we can look more closely at some of the above effects.

Electronic Keyboard

The small portable keyboard had the advantage of reasonably pure, sustained tones and a convenient size for making measurements around the room. I adjusted the volume for a level of 85dB at one metre and proceeded to play up and down the scales as I moved to various places in the room.

The results will come as no surprise to anyone familiar with puretone level checks. The geometry of the room will reflect certain notes beautifully if you happen to be at the proper angle (and playing that note); if the echoes reinforce each other, a peak in the response called a *standing wave peak* will happen. As a result, some notes in some locations were actually higher on the meter as you got farther away. Some notes that sounded identically loud to the ear produced widely different readings due to cancellations as echoes meet out of phase; the physical point of cancellation is called a *node.*

The output of the meter is fed into a scope; at the moment it's reading the whirring of the camera shutter.

Acoustic Guitar

The guitar's loudest notes tended to be the low E and A strings, with 80 to 83dB at one metre. Plucked together, they summed to 84 or 85dB; it's a bit hard to tell with transients like guitar notes. The level fell off somewhat as I went up the scale, presumably because the guitar top and braces were made to resonate freely in the E-A region. This doesn't mean that the guitar is bass-heavy. It actually sounds nicely balanced, pointing out the ear's relative insensitivity to low frequencies.

Tin Whistle

The tin whistle, or pennywhistle, is not made of tin and costs a whole lot of pennies, but manages a shriek of 100dB in its second octave. The weaker, higher notes only fell off by 4 or 5dB. Proof positive that they're not the sort of thing to start practising on at 3AM.

The relatively pure tones from the whistle created lovely standing waves as I walked around creating confusing readings all over the place.

Banjo

No surprises here. The plunky twang registered 80 to 85 with finger-style playing, 90 on loud chording. The standing waves weren't that much of a problem as I walked around; the sudden short notes weren't around long enough to create noticeable peaks or nodes.

Violin

Readings of 90dB weren't difficult to produce on any string. Only the very highest notes fell off, though I suspect a better player could have coaxed a louder, purer tone on the top strings right up to 90dB and more.

The biggest surprise was to place the meter's microphone where the player's left ear would be, very close to the belly and bridge of instrument. With this setup, readings of 105-110dB were common with C weighting, and 105 was routine with A weighting. Yet 90dB is the level at which you're warned about excessive exposure by the industrial safety people ("prolonged exposure may result in hearing damage...").

Even if you allow for the fact that musicians don't play constantly for eight hours a day, 105dB is a pretty loud sound to put in your ear. Violinists don't all seem to be deaf on the left, though maybe they are and they've been hiding it. Could it be that the *type* of sound is important when it comes to damage? I imagine that percussive sounds would be more damaging than violin tones. A rock concert, for instance, will make your ears ring, while a symphony orchestra won't, no matter how long the fortissimos last.

Reed Organ

This one was unusual. I have a 19th century foot-pumped reed organ in the living room, and when I measured its output (only 80dB – it was meant for polite young ladies who were entertaining the vicar), I found it varied by only plus-or-minus 2dB as I went up and down the scale, performance that would turn a high-end speaker manufacturer green with envy. Usually the room acoustics skew the response far more than that, and I'm not sure of the explanation, other than lucky placement and the richness of the reed tone (the rich odd harmonics don't excite standing waves the same way as pure tones).

Room Acoustics

The manual that comes with the meter has a section on adjusting the response of a sound system to compensate for room acoustics. The preferred method is to play a test record or tape that "should produce pure tones, one at a time, at intervals spanning the audio spectrum". An adjustable oscillator can substitute for a test record. A frequency equalizer will be much more versatile for this than the usual bass and treble controls. Also, furniture can be moved around, within limits, of course. Spouses do not take kindly to finding the window drapes hanging across the fireplace because it sounds better.

There's a caution here. When I worked in recording studios, it wasn't unusual to see a technician with sound level meter in hand, following the instructions given above. However, the results were often worse than before because of the standing wave peaks and nodes. A room is a very complex resonator; moving the meter six inches during a pure tone can change the measurement by 10dB or more. The room is just *full* of humps and dips, and "chasing the needle" is only going to muddle things up.

The usual way around the standing wave problem in professional applications is to use white noise (or *pink noise*, which has a flatter amplitude when displayed on a chart recorder because it's attenuated with rising frequency). The advantage of noise is that it's made up of all frequencies, preventing the excitation of standing waves. The disadvantage is that you need a sophisticated spectrum analyzer in order to see what's happening in specific frequency bands. The analyzer does this by using filter "windows", usually 1/3 octave wide; there are usually lots and lots of these windows showing the entire audio spectrum on a video display. A bit of overkill if you're only setting up a hifi system.

The simplest method is simply to stay aware of the tricks that room acoustics will play on you when you use pure tones. Don't start adjusting things just because you see a peak or dip; move around and take lots of readings first. If you're using an adjustable oscillator, slowly sweep it back and forth in frequency around the spot that's causing a suspect reading.

And, of course, when it comes down to it, your ear should rule. The equalizer may keep the meter happy at a particular spot while the rest of the room sounds wrong. Experimenting is the key. ■