LOW-END EXPLORATION

Looking into the directional behavior of subwoofers.

by Merlijn van Veen

> “*When a loudspeaker is reproducing sound with a wavelength considerably larger than the size of its enclosure, we all know that it should be essentially omnidirectional and send out sound waves spherically.” —John Vanderkooy (BEng, PhD, and distinguished professor emeritus at University of Waterloo)*

Despite Dr. Vanderkooy’s statement, when we walk around a subwoofer we can clearly hear that it’s directional. What’s going on? The devil is in the details.

Here’s a brief summary of a practical experiment that I do during my Level II seminars that helps reveal some of those details. We begin by creating a polar circle on the floor typically 6 meters (18 feet) in diameter (shown in the image above). I put a calibrated measurement microphone at all cardinal points (north, south, east and west) and insert a rough value for each delay locator in Rational Acoustics Smaart (typically the length of the radius in meters times 3 milliseconds).

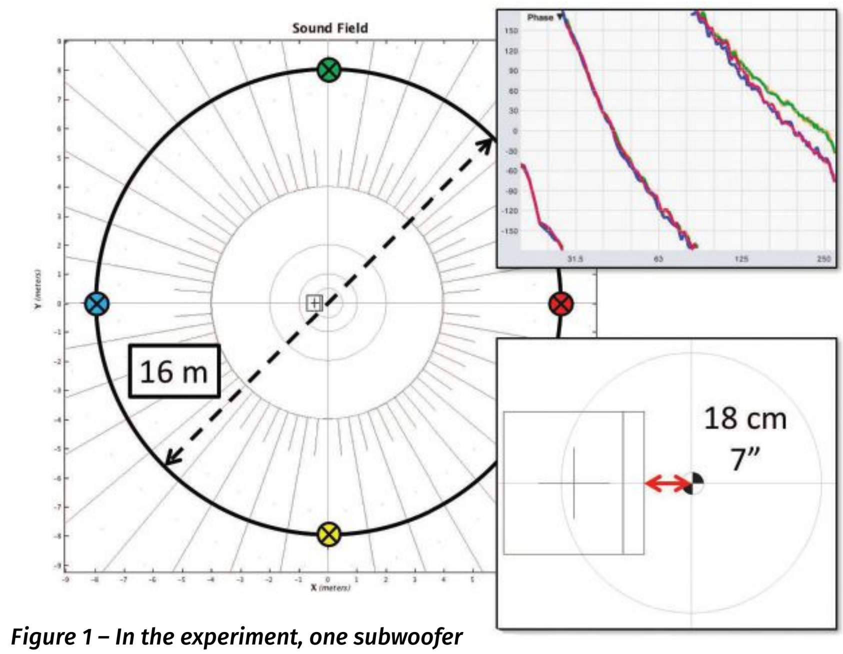

Figure 1 – In the experiment, one subwoofer ended up about 18 centimeters (7 inches) from the center of the circle.

Then I ask the participants to physically position a single subwoofer so that all four phase traces match to the best of their abilities. Using the same baseline value in the delay locator for each measurement microphone implies that matched phase traces indicate matched times-of-flight, and therefore distance.

The last time we did this experiment, a Meyer Sound USW-1P compact subwoofer ended up about 18 centimeters (7 inches) from the center of the polar circle with respect to the front grille (**Figure 1**). Larger-format subwoofers can end up as

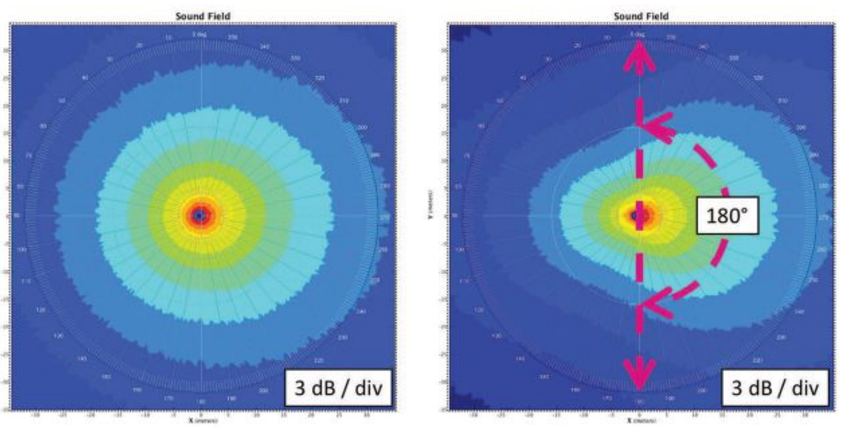

Figure 2: The plot at left (63 Hz) is what we expect to hear, but the plot at right (160 Hz, biased) is what we actually hear.

The configuration of the author’s seminar experiment.

much as 1 foot from the center.

Once the subwoofer is in it's particular place, I ask the participants to walk along the edge of the circle while listening to pink noise. Typically we all agree that there's audible directivity, which is counterintuitive. We expect something resembling the left-side plot in **Figure 2** but experience the right-side plot, which exhibits a coverage angle of "only" 180 degrees – not 360 degrees.

The equal-loudness contours (ELC, **Figure 3**) show us that human hearing exhibits about 40 dB (100:1 ratio) of variance in pressure sensitivity for the subwoofer range (32 Hz to 125 Hz). This means that we're partial to the higher subwoofer frequencies by at least 20 dB or more. Listening to subwoofers alone, without mid and high frequencies, puts our perception completely out of context, so we're well advised to desensitize ourselves when gauging directivity.

Using the ELC curves as weighting curves allows us to see the subwoofer in Smaart the way that we hear it. For subs running at 90 to 100 dB SPL (Z-weighted), I typically resort to the 50 or 60 phon curve. Note: An equal-loudness contour is a measure of sound pressure (dB SPL) for which a listener perceives a constant loudness when presented with pure steady tones. The unit of measurement for loudness levels is the phon. The equal-loudness contours map the way from the dB SPL of a pure tone to the perceived loudness level in phons.

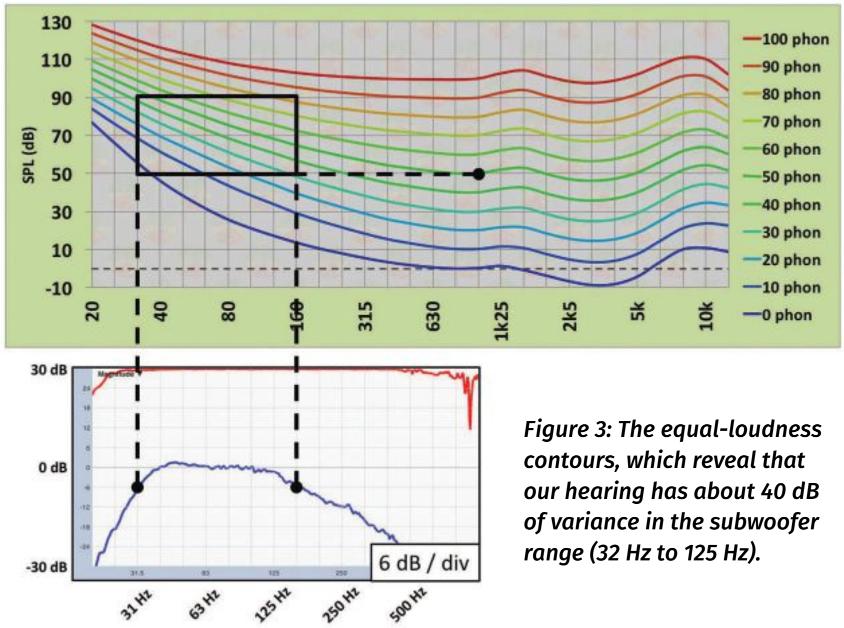

Figure 3: The equal-loudness contours, which reveal that our hearing has about 40 dB of variance in the subwoofer range (32 Hz to 125 Hz).

Figure 4 shows that for the USW-1P subwoofer used in this particular experiment, we're 24 dB (16 times) more sensitive to the octave between 125 and 250 Hz. This resides outside the actual operational range of this loudspeaker.

When left uncounted for, we end up listening to a completely different frequency band, where typically, the main loudspeakers are sole custodians. The perceived bandwidth differs from the measured (Z-weighted) bandwidth. Needless to say, this will completely skew our perception, including that of directivity.

It took a 2nd-order Linkwitz-Riley lowpass filter at 32 Hz to make the subwoofer sound "flat" to our ears. The filter was introduced for listening purposes only in order to unbias ourselves. Once the filter was in place, we walked the circle again and suddenly any signs of directivity were virtually gone.

With the subwoofer equitemporal (and thus equidistant) to all cardinal points, it sounded and measured near omnidirectional. What we heard under these circumstances matched our expectations (the left side of **Figure 2**). From this experiment, we've found that small-format subwoofers tend to be down by 1 dB in the back while larger subwoofers can be down by as much as 3 dB. LSI

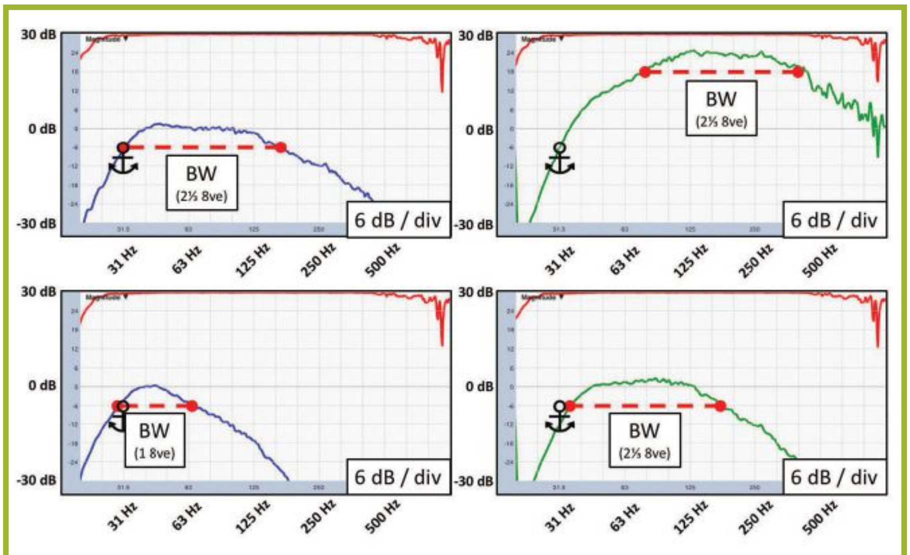

Figure 4: On the left, what it measures like (Z weighted), while on the right, what it actually sounds like (50-phon weighted).

*Based in The Netherlands, **Merlijn van Veen** (https://www.merlijnvanveen.nl) is a consultant specializing in sound system design and optimization, and he's also a noted audio educator.*