The New Ellipticor Drivers from Scan-Speak

By Vance Dickason

I have been anxiously awaiting these new oval voice coil drivers ever since the first press release on the Scan-Speak Ellipticor drivers was featured on the cover of the July 2017 issue of *Voice Coil*. Using an oval (elliptical) voice coil shape to defeat cone and dome standing wave modes is compelling concept.

Scan-Speak has tried different techniques over the years to suppress cone modes (a source of coloration), the most notable one being the Revelator sliced cone series of woofers such as the 18W-4531G00 shown in **Photo 1**. With this concept, cone modes are suppressed by angled slices in the cone that are glued back together. This product was extremely popular in the high-end two-channel market when it was introduced.

Evidently, the idea of using elliptical-shaped voice coils to control cone and dome modes came from an engineering brain storming session that involved Birger

Photo 1: Scan-Speak's the 18W-4531G00, one of the Revelator sliced cone series

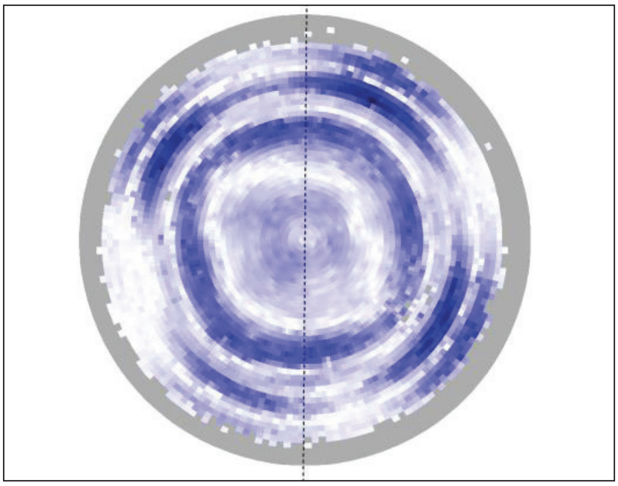

Photo 2: A cone driven symmetrically with a round voice coil

Jorgensen (sadly Birger passed nearly two years ago). One of the goals for a new driver concept at Scan-Speak was to minimize cone modes, so it was kind of a joke to suggest an elliptical voice coil, but some engineering humor that had some solid science behind it. By not driving the diaphragm asymmetrically, what you get is an "infinite" number of Eigen frequencies, but with less contribution for each frequency and overall lower distortion. Driving the diaphragm symmetrically you get a finite number of Eigen frequencies with a higher contribution combining at certain frequencies

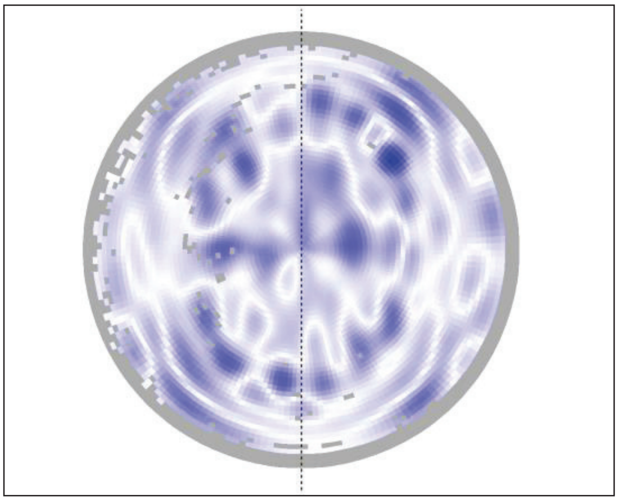

Photo 3: A cone driven asymmetrically with a elliptical voice coil

Photo 4: The Ellipticor D3404/552000 tweeter (a); a close up of the tweeter's front (b); and the back (c)

producing the "dreaded" coloration modes. **Photo 2** and **Photo 3** show the mode difference using finite element analysis (FEA) with a scanning vibrometer technique to visualize the difference between a cone driven symmetrically with a round voice coil (see Photo 2) versus a cone driven asymmetrically with a elliptical voice coil (see Photo 3). I should also note that the concept of using asymmetry to suppress diaphragm modes, not with an asymmetrical voice coil, but by using an asymmetrical diaphragm with a round coil was patented by Enrique Stiles, my friend,

Photo 5: The 18WE/4542T00 7" diameter midbass driver (a); a close up of the driver's front (b); and the back (c)

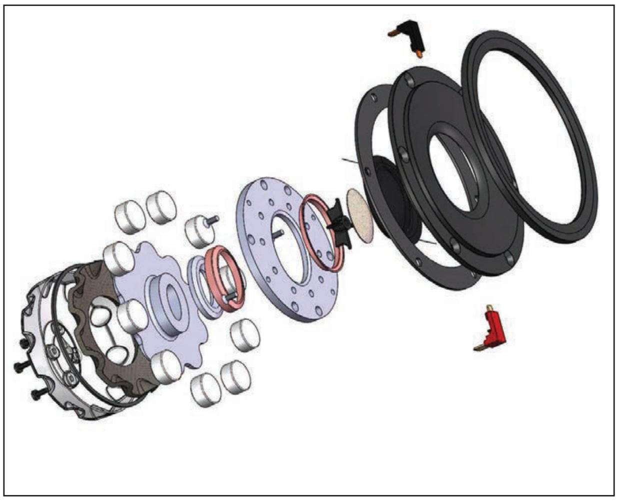
Photo 6: The exploded diagram for the D3404/552000

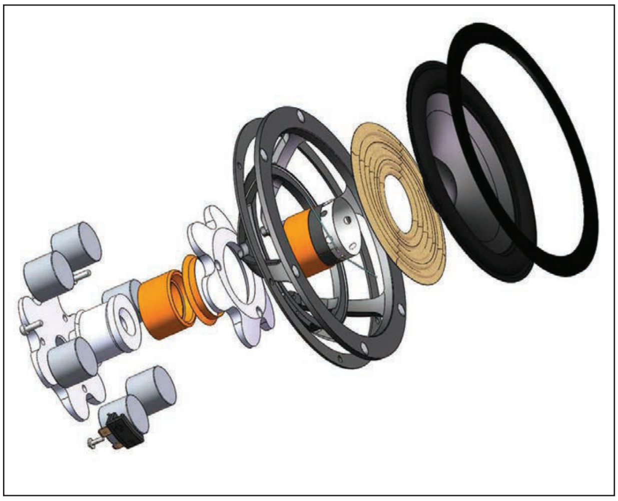

Photo 7: The exploded diagram for the 18WE/4542T00

consulting associate, and extremely clever transducer engineer, in US Patent Number 7177440.

From this exciting concept, developed at Scan-Speak, came the two elliptical voice coil samples that the company sent me for this installment of Test Bench, the Ellipticor D3404/552000 tweeter depicted in **Photo 4** and the 18WE/4542T00 7″ diameter midbass driver shown in **Photo 5**. **Photo 6** and **Photo 7** show the exploded diagrams for the D3404/552000 and the 18WE/4542T00, respectively.

The D3404/552000

The first elliptical voice coil device I characterized this month was the Scan-Speak Ellipticor D3404/552000 dome neodymium motor tweeter. Overall, the D3404/552000 is a big tweeter with a diaphragm Sd (11.4 cm^2) equal to somewhere between a 38 mm (14 cm^2) and a 28 mm (8.5 cm^2) conventional round dome tweeters. The voice coil diameter is 28 mm × 39 mm, so you could think of it as an elongated 28 mm diameter tweeter.

For a motor system, Scan-Speak basically scaled up their currently successful Air-Circ tweeter motor with 10 (versus six slugs for the original Air-Circ motors)

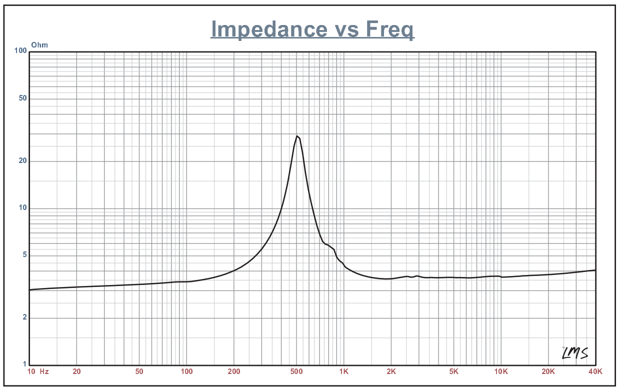

Figure 1: Scan-Speak Ellipticor D3404/552000 impedance plot

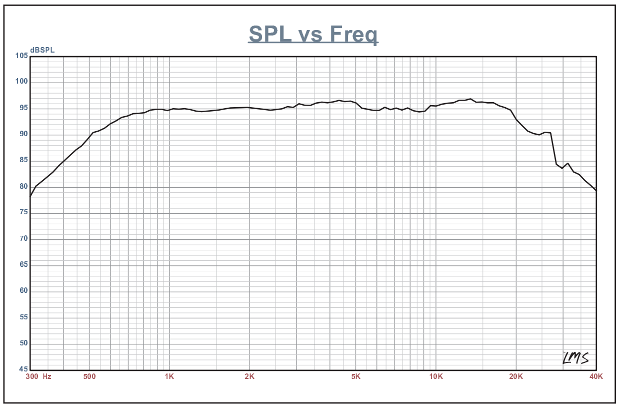

Figure 2: Scan-Speak Ellipticor D3404/552000 on-axis response

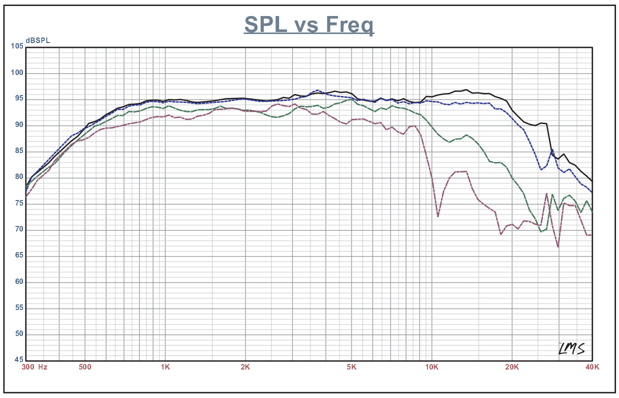

Figure 3: Scan-Speak Ellipticor D3404/552000 horizontal on- and off-axis frequency response (0° = black; 15° = blue; 30° = green; 45° = purple)

neodymium slugs and copper shorting rings (part of the patented Symmetrical Drive SD-2 motor format) and a titanium former.

The motor system is underhung like most tweeters, and has a gap height of 3 mm and a voice coil length of 2.5 mm for a 0.25 mm Xmax. The big news is that this motor and diaphragm yield a 2.83 V/1 m sensitivity of 97 dB!

Other features include a coated cloth elliptical dome, aluminum face plate, gold-plated terminals, and a very slick aluminum trim ring that covers the mounting screws. This "beauty" ring snaps into place and is held tight through the use of three neodymium magnets mounted on the underneath side around it peripheral.

I used the LinearX LMS analyzer to produce the 300-point impedance sweep illustrated in **Figure 1**. The D3404/552000's impedance resonance occurs at 500 Hz (factory spec is 475 Hz). With a 3.31 Ω DCR (the factory spec is 3.0), the minimum impedance for this tweeter measures 3.56 Ω at 1.9 kHz.

Following the impedance testing, I recess mounted the Ellipticor tweeter in an enclosure that had a baffle area of 22" × 12" and measured the on- and off-axis frequency response. I spoke with LOUDSOFT representatives at AISE 2018 and they are planning to send me their new FINE Hardware 3, which is a 192 kHz two-channel analyzer, capable of measuring tweeters out to 40 kHz (the LOUDSOFT analyzer I

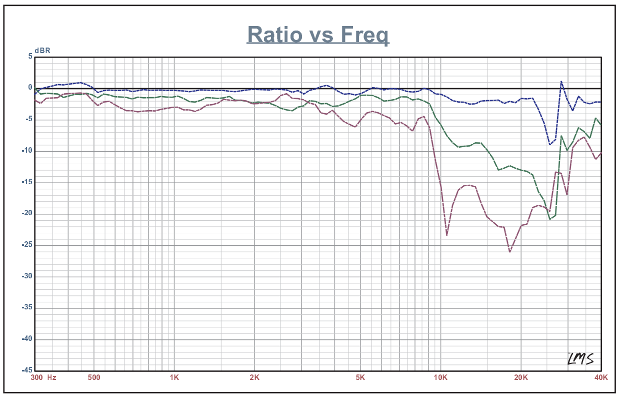

Figure 4: Scan-Speak Ellipticor D3404/552000 normalized on- and off-axis frequency response (0° = black; 15° = blue; 30° = green; 45° = purple)

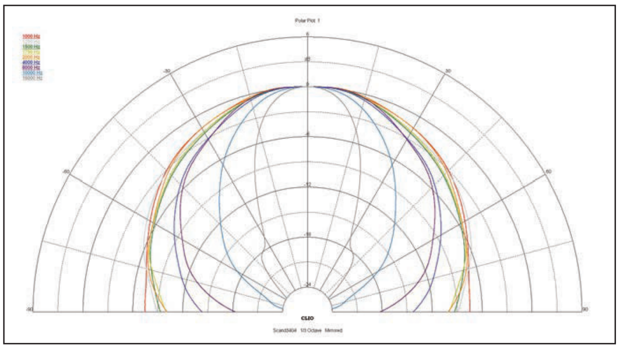

Figure 5: Scan-Speak Ellipticor D3404/552000 180° horizontal plane CLIO polar plot (in 10° increments)

am currently using only measures SPL to 20 kHz). However, it might be a month or so before I receive it. Since the Ellipticor driver is such a unique new offering for the industry, I decided to measure the SPL using the LinearX LMS analyzer for this explication, as it goes out to 40 kHz. So, I set up the LMS analyzer to 100-point gated sine wave sweeps at 2.83 V/1 m. **Figure 2** shows the on-axis response to be a smooth ± 2 dB from 730 Hz to 20 kHz, and ±1 dB from 1.7 kHz to 18 kHz.

Figure 3 depicts the on- and off-axis (0° to 45°) response of D3404/552000. The off-axis curves normalized to the on-axis response are shown in **Figure 4**. **Figure 5** shows the CLIO 180° polar plot (measured in 10° increments). These measurements were all made with the D3404/552000 dome in the normal vertically oriented position. Since the height of the dome is greater than the width, I decided to investigate if there was any vertical directivity. **Figure 6** gives the on- and off-axis with the tweeter in a horizontal orientation. Since it's a bit hard to compare with Figure 3, I compared them to orientations at both 30° off-axis (see **Figure 7**) and both orientations at 45° off-axis (see **Figure 8**). Most of the variation comes above 10 kHz where the response is rapidly declining, so I really think vertical directivity due to the diaphragm's shape is trivial and not really much of a concern. The last SPL

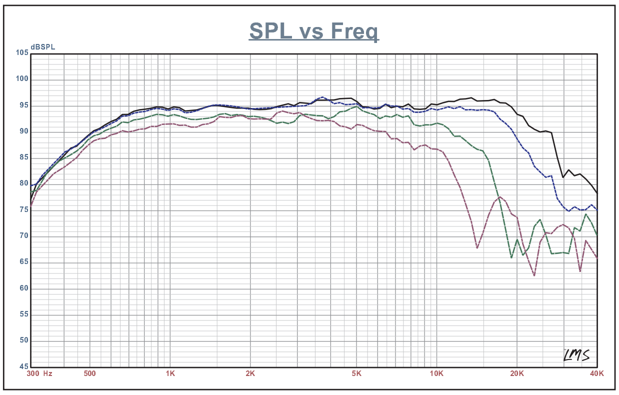

Figure 6: Scan-Speak Ellipticor D3404/552000 vertical on- and off-axis frequency response (0° = black; 15° = blue; 30° = green; 45° = purple)

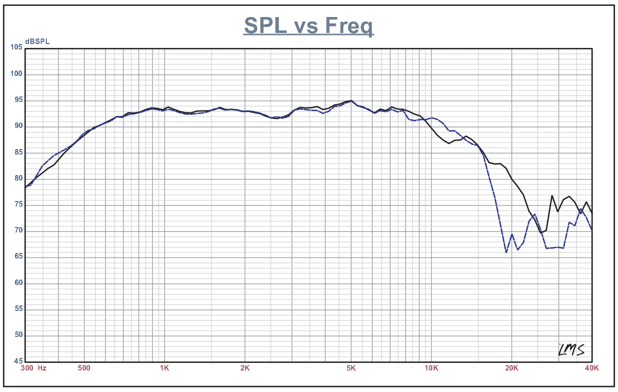

Figure 7: Scan-Speak Ellipticor D3404/552000 comparison of 30° off-axis curve from Figure 3 and Figure 6

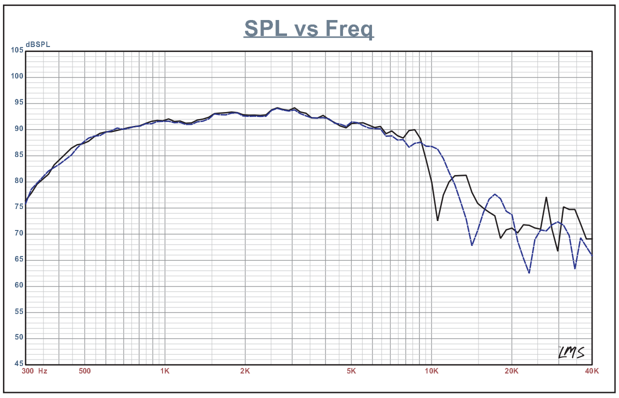

Figure 8: Scan-Speak Ellipticor D3404/552000 comparison of 45° off-axis curve from Figure 3 and Figure 6

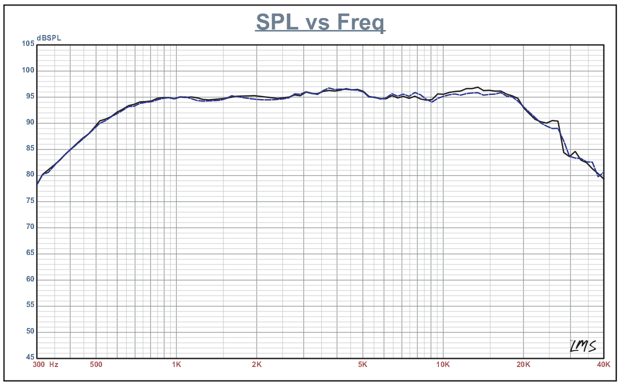

Figure 9: Scan-Speak Ellipticor D3404/552000 two-sample SPL comparison

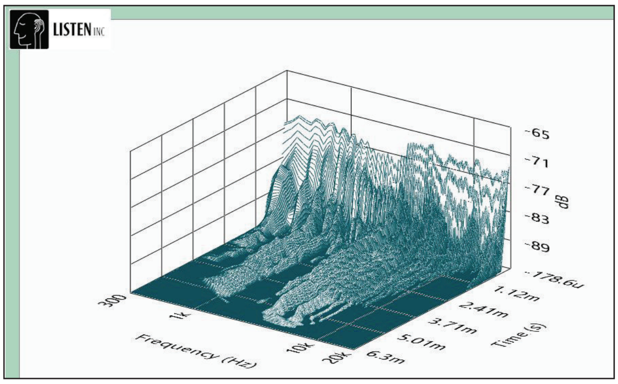

Figure 10: Scan-Speak Ellipticor D3404/552000 SoundCheck CSD waterfall plot

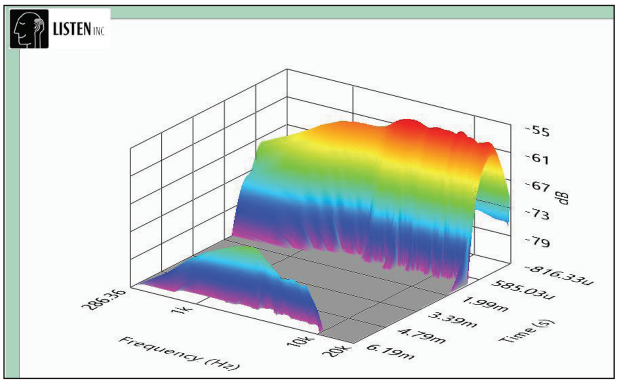

Figure 11: Scan-Speak Ellipticor D3404/552000 SoundCheck STFT surface intensity plot

measurement was the two-sample SPL comparison (see **Figure 9**), indicating the two samples were closely matched to within less than 1 dB throughout the driver's operation range.

The next test sequence in the Test Bench protocol was to use the Listen, Inc. AudioConnect analyzer along with the Listen SCM 0.25" microphone and SoundCheck 16 software (provided courtesy of Listen, Inc.) to measure the impulse response with the Ellipticor tweeter recess mounted on the test baffle. Importing this data into the Listen SoundMap software produced the cumulative spectral decay (CSD) plot (usually referred to as a "waterfall" plot) shown in **Figure 10**. **Figure 11** shows the Short Time Fourier Transform (STFT) displayed as a surface plot.

For the last test procedure, I set the 1 m SPL to 94 dB (2.34 V) using a pink noise stimulus, and measured the second (red curve) and third (blue curve) harmonic distortion at 10 cm (see **Figure 12**). Note the third-harmonic distortion is extremely low, less than 0.4%. All things taken together, this is an impressive accomplishment for Scan-Speak.

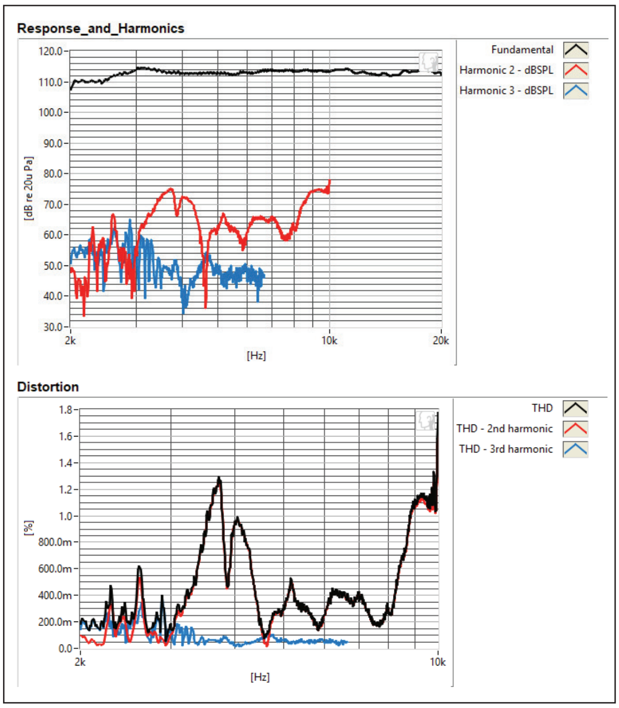

Figure 12: Scan-Speak Ellipticor D3404/552000 SoundCheck distortion plots

The 18WE/4542T00

I next started setting up to measure the Scan-Speak 7" 18WE/4542T00 Ellipticor midwoofer. Like the D3404, the 18WE/4542T00 is a seriously feature-rich transducer. Starting with the frame, like most of Scan-Speak's midwoofer/midrange frames, the 18WE frame is a nicely configured three double spoke (six total) cast-aluminum frame with narrow 12 mm wide spokes to minimize reflections back into the cone. The area below the suspended spider mounting shelf is almost completely open, resulting in effective cooling of the motor and voice coil. For the cone assembly, Scan-Speak chose a rather stiff curvilinear profile back coated paper cone with an elliptical 45 mm × 35 mm convex paper dustcap. Compliance is provided

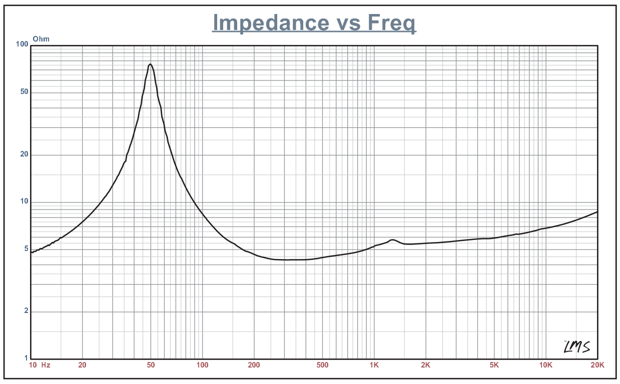

Figure 13: Scan-Speak Ellipticor 18WE/4542T00 midwoofer 1 V free-air impedance plot

	TSL Model		LTD Model		Factory
	Sample 1	Sample 2	Sample 1	Sample 2	
F_S	52 Hz	49.5 Hz	50.2 Hz	47.9 Hz	46.0 Hz
R_{EVC}	3.40	3.39	3.40	3.39	3.4
Sd cm²	141	141	141	141	133
Q_{MS}	5.91	6.26	5.03	6.03	5.62
Q_{ES}	0.29	0.29	0.25	0.25	0.26
Q_{TS}	0.27	0.27	0.24	0.25	0.25
V_{AS}	15.1 ltr	16.7 ltr	16.4 ltr	18 ltr	17.2 ltr
SPL 2.83 V	90.6 dB	90.4 dB	91 dB	90.7 dB	92.5 dB
X_{MAX}	7.25 mm	7.25 mm	7.25 mm	5.25 mm	7.2 mm

Table 1: Scan-Speak 18WE/4542T00 data comparison

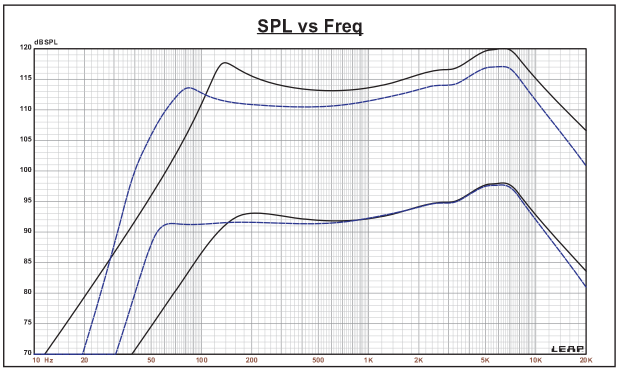

Figure 14- Scan-Speak Ellipticor 18WE/4542T00 computer box simulations (black solid = sealed at 2.83 V; blue dash = vented at 2.83 V; black solid = sealed at 58 V; blue dash = vented at 33V)

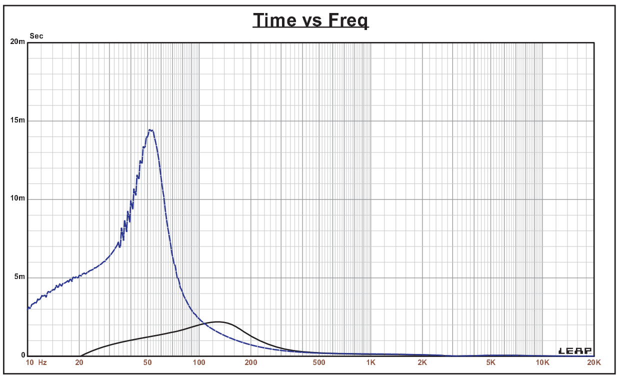

Figure 15: Group delay curves for the 2.83 V curves shown in Figure 14

by an NBR surround, nicely designed with a shallow discontinuity where it attaches to the cone edge plus a surface coating for enhanced damping in that critical region. Remaining compliance comes from a 4" diameter flat cloth spider.

The motor design for the Ellipticor 18WE/4542T00, as with the D3404/552000, is also an Air-Circ multi magnet design utilizing six 22 mm high and 25 mm diameter neodymium slugs with a black emissive coating. This is also one of Scan-Speak's patented SD motor systems and so incorporates copper shorting rings (Faraday shields). FEA designed, the neodymium magnet motor uses a 35 mm × 45 mm elliptical two-layer voice coil wound with round copper wire on a titanium former. Motor parts include polished front and back plates for the neodymium magnets that incorporate a 12 mm diameter rear vent for additional cooling.

As with the D3404/552000 tweeter, the 18WE/4542T00 has a magnetically attached aluminum trim ring that can obviously be anodized a variety of colors besides black. Last, the voice coil is terminated to a pair of gold-plated terminals. In terms of physical appearance, this driver is simply stunning.

I began analysis of the 18WE/4542T00, using the LinearX LMS analyzer and VIBox to create both voltage and admittance (current) curves, with the

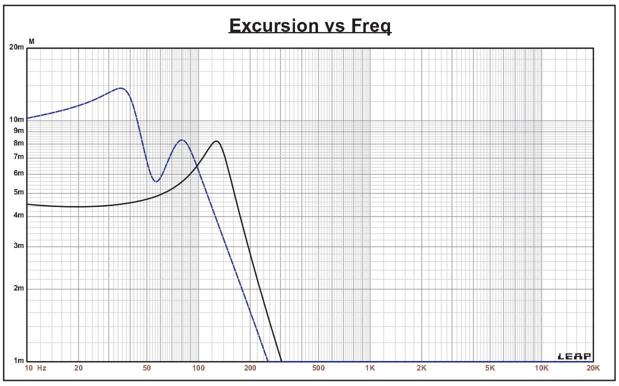

Figure 16: Cone excursion curves for the 58 V/33 V curves shown in Figure 14

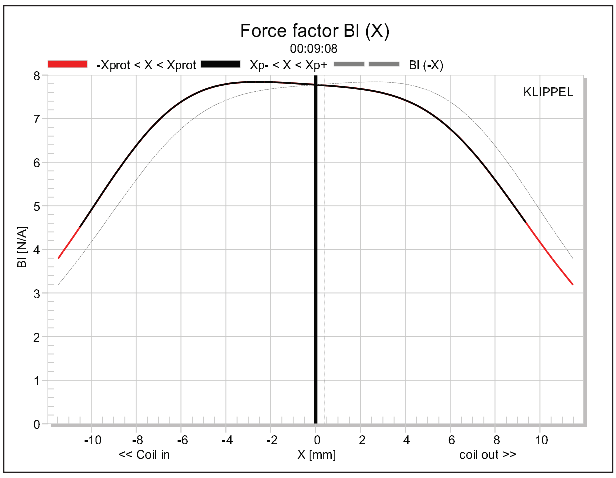

Figure 17: Klippel analyzer Bl (X) curve for the Scan-Speak Ellipticor 18WE/4542T00

driver clamped to a rigid test fixture in free-air at 0.3 V, 1 V, 3 V, 6 V, 10 V, and 15 V. As with almost all 6.5″ to 7″ diameter woofers, 10 V curves are usually too nonlinear for LEAP to get a reasonable curve fit and usually have to be discarded, however, due to the linearity and fairly high Xmax of the 18WE/552000, I was able to use all the curves including the 15 V curves, which is unusual for this diameter midbass driver.

As has become the protocol for Test Bench testing, I no longer use a single added mass measurement to determine Vas. Instead, I use the actual measured cone assembly mass (Mmd) supplied by the driver manufacturer, which was 16.5 grams for the Scan-Speak 7″ woofer. Next, I post-processed the 12 550-point stepped sine wave sweeps for each Ellipticor 18WE sample and divided the voltage curves by the current curves (admittance) to derive impedance curves, phase added by the LMS calculation method. Along with the accompanying voltage curves, I imported the data into the LEAP 5 Enclosure Shop software. Since most Thiele-Small (T-S) data provided by the majority of OEM manufacturers is generated

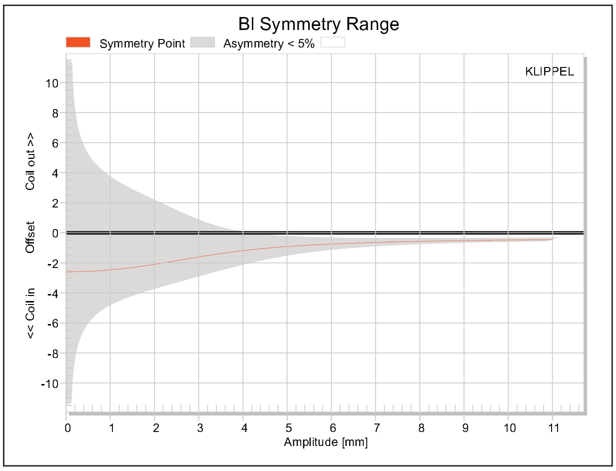

Figure 18: Klippel analyzer Bl symmetry range curve for the Scan-Speak Ellipticor 18WE/4542T00

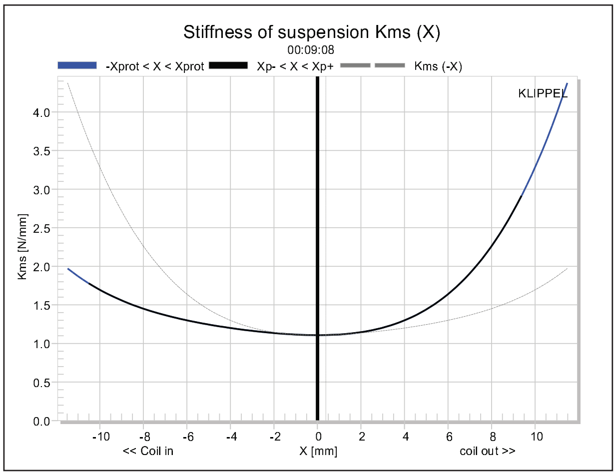

Figure 19: Klippel analyzer mechanical stiffness of suspension Kms(X) curve for the Scan-Speak Ellipticor 18WE/4542T00

using either the standard model or the LEAP 4 TSL model, I additionally created a LEAP 4 TSL parameter set using the 1 V free-air curves. I selected the complete data set, the multiple voltage impedance curves for the LTD model, and the 1 V impedance curve for the TSL model in the transducer derivation menu in LEAP 5 and created the parameters for the computer box simulations. **Figure 13** shows the 1 V free-air impedance curve. **Table 1** compares the LEAP 5 LTD, TSL and factory published parameters for both of Scan-Speak 18WE/4542T00 samples.

LEAP parameter calculation results for the Ellipticor 18WE/4542T00 were close to the published factory data. I followed my normal protocol and began setting up computer enclosure simulations using the LEAP LTD parameters for Sample 1. I programmed two computer box simulations into LEAP 5, one a Butterworth sealed box with a 140 in^3 volume 50% fiberglass damping material and a vented enclosure with a 0.65 ft^3 volume tuned to 55 Hz with 15% fiberglass fill material.

Figure 14 displays the results for the Ellipticor

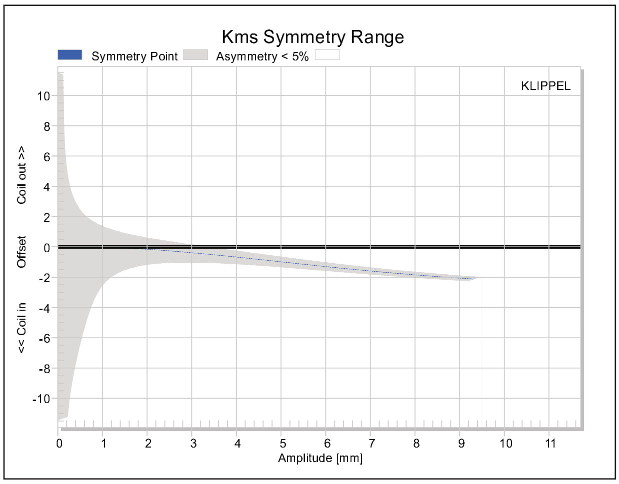

Figure 20: Klippel analyzer Kms symmetry range curve for the Scan-Speak Ellipticor 18WE/4542T00

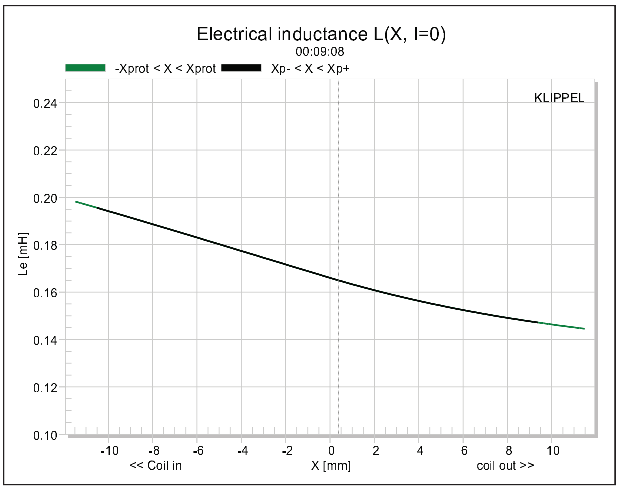

Figure 21: Klippel analyzer L(X) curve for the Scan-Speak Ellipticor 18WE/4542T00

18WE/4542T00 in the vented and sealed boxes at 2.83 V and at a voltage level sufficiently high enough to increase cone excursion to Xmax + 15% (8.3 mm for the 18WE/4542T00). This produced a F3 frequency of 126 Hz (F6 = 102 Hz) with a Qtc = 0.68 for the sealed enclosure and –3 dB = 51 Hz (F6 = 46 Hz) for the vented box. Increasing the voltage input to the simulations until the maximum linear cone excursion was reached resulted in 117.7 dB at 58 V for the sealed enclosure simulation and 114 dB for a 33 V input level for the vented enclosure. **Figure 15** shows the 2.83 V group delay curves. **Figure 16** shows the 58/33 V excursion curves. The sealed box simulation volume is really too small to be practical, which suggest that if you were to use this woofer in a three-way system crossed at 150 to 200 Hz, it would be better to use a larger volume with a lower Qtc.

Klippel analysis for the Scan-Speak 7″ midwoofer (produced the Bl(X), Kms(X), and Bl and Kms symmetry range plots shown in **Figures 17–20**.

(Our analyzer is provided courtesy of Klippel GmbH and the analysis was performed by Pat Turnmire, Redrock Acoustics. This data is extremely valuable for transducer engineering, so if you don't own a Klippel analyzer and would like to have analysis done on a particular project, visit www.redrockacoustics.com.)

The Bl(X) curve (see Figure 17) is mostly symmetrical with a small amount of tilt and coil-in offset, however this is fairly broad Bl curve for a 6.5″ to 7″ woofer. Looking at the Bl symmetry plot (see Figure 18), from an area of reasonable certainty (the grey overlay) at 5.5 mm the coil-in offset is 0.8 mm gradually decreasing coil-in offset that is only 0.56 mm the drivers Xmax +15% position (8.3 mm), which is rather minor.

Figure 18 and Figure 19 show the Kms(X) and Kms symmetry range curves. The Kms(X) curve is not as symmetrical in both directions as the Bl curve, and shows an increasing coil-in offset that reaches 1.62 mm at the physical Xmax position, which is not critical.

Displacement limiting numbers calculated by the Klippel analyzer for the Scan-Speak 18WE/4542T00 were XBl @ 82% Bl = 6.7 mm and for crossover (XC) at 75% Cms minimum was 5.2 mm, which means that for this Ellipticor midwoofer, the compliance is

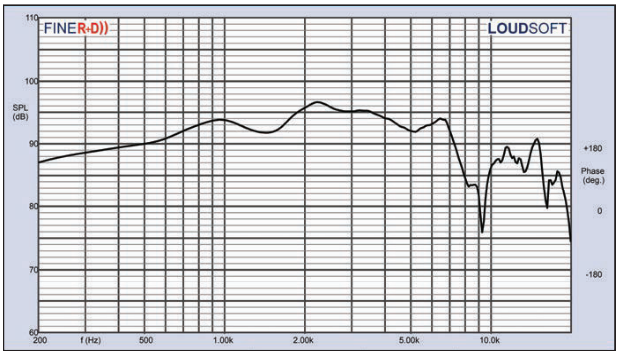

Figure 22: Scan-Speak Ellipticor 18WE/4542T00 on-axis frequency response

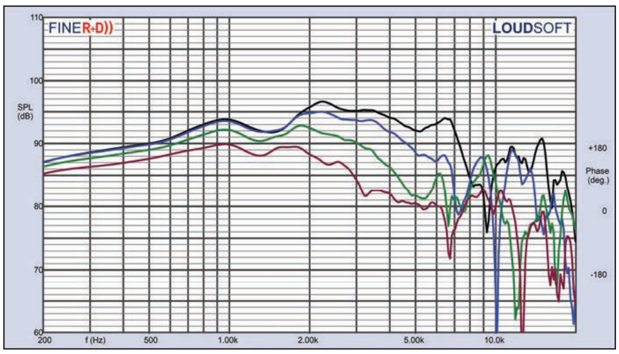

Figure 23: Scan-Speak Ellipticor 18WE/4542T00 horizontal on- and off-axis frequency response (0° = black; 15° = blue; 30° = green; 45° = purple)

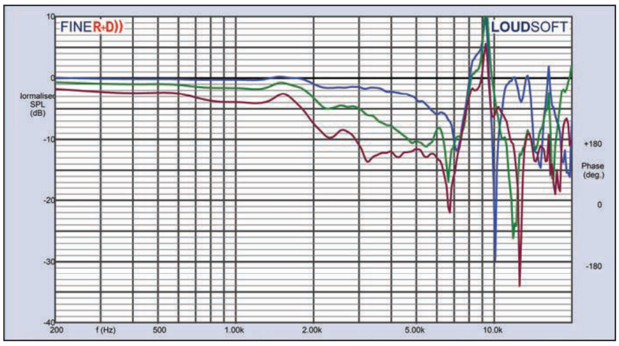

Figure 24: Scan-Speak Ellipticor 18WE/4542T00 normalized on- and off-axis frequency response (0° = black; 15° = blue; 30° = green; 45° = purple)

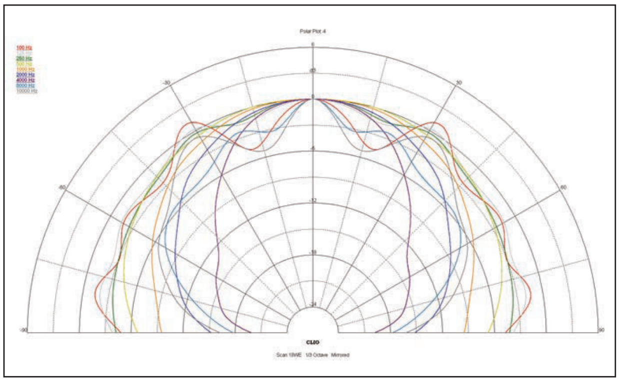
Figure 25: Scan-Speak Ellipticor 18WE/4542T00 180° horizontal plane CLIO polar plot (in 10° increments)

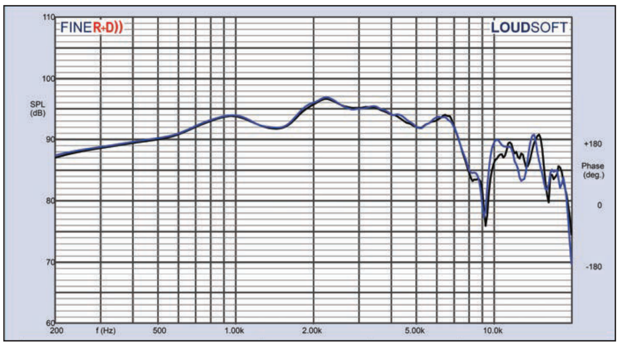

Figure 26: Scan-Speak Ellipticor 18WE/4542T00 midwoofer two-sample SPL comparison

the most limiting factor for prescribed distortion level of 10%. If we use a less conservative 20% distortion criteria of Bl falling to 70% of its max value and compliance falling to 50% of it maximum value, the

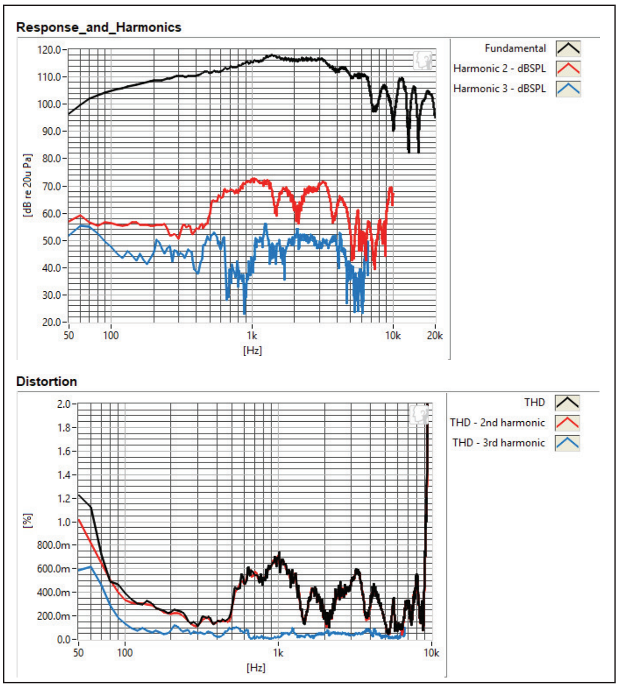

Figure 27: Scan-Speak Ellipticor 18WE/4542T00 SoundCheck distortion plot

numbers would be XBl = 8.2 mm and XC = 7.9, with both numbers being greater than physical 7.25 mm driver's Xmax.

Figure 21 gives the inductance curves Le(X) for the 18WE/4542T00. Inductance will typically increase in the rear direction from the zero rest position as the voice coil covers more pole area, which is what you see here. However, because of the effective use of copper shorting rings, the inductive swing from Xmax in to Xmax out is a very small 0.037 mH, which is very good performance.

With the Klippel testing completed, I mounted the Ellipticor 18WE/4542T00 woofer in an enclosure, which had a 15" × 8" baffle and was filled with damping material (foam). Then, I used the LOUDSOFT FINE R+D FFT analyzer to measure the device under test (DUT) on and off axis from 300 Hz to 40 kHz frequency response at 2.83 V/1 m. **Figure 22** gives the 18WE/4542T00's on-axis response indicating a smoothly rising response to about 4 kHz where it begins its low-pass roll-off.

Figure 23 shows the on- and off-axis frequency response at 0°, 15°, 30°, and 45°. The -3 dB frequency at 30° off-axis relative to the on-axis SPL is about 2 kHz, suggesting a crossover between 1.8 to 2.5 kHz should be appropriate. **Figure 24** shows the normalized version of Figure 23, with the CLIO polar plot (done in 10° increments) displayed in **Figure 25**.

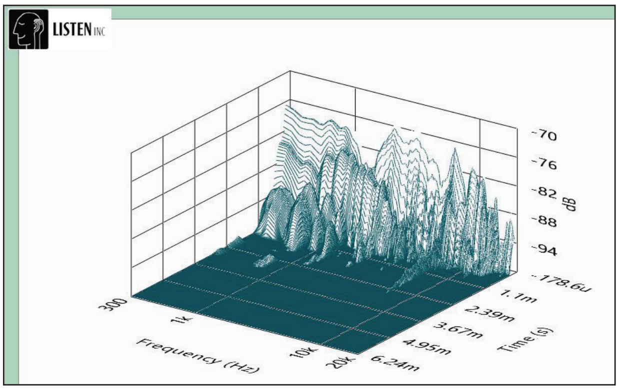

Figure 28: Scan-Speak Ellipticor 18WE/4542T00 woofer SoundCheck CSD waterfall plot

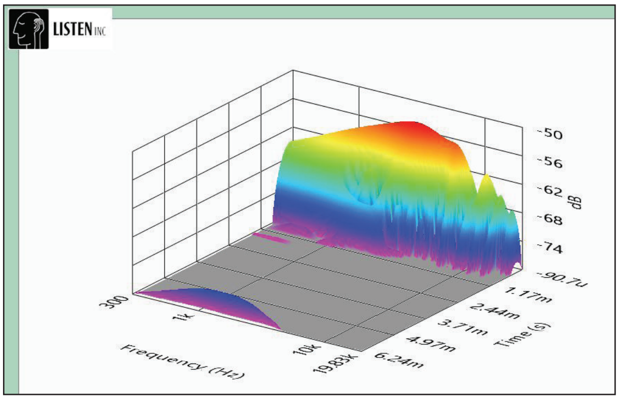

Figure 29: Scan-Speak Ellipticor 18WE/4542T00 midwoofer SoundCheck Wigner-Ville plot

And finally, **Figure 26** gives the two-sample SPL comparisons for the 7" Ellipticor driver, showing a close match (less than 0.5 dB variation) throughout the operating range.

For the remaining series of tests on the Scan-Speak 18WE/4542T00, I again employed the Listen SoundCheck 16 software, AudioConnext analyzer, and SCM microphone to measure distortion and generate time-frequency plots. For the distortion measurement, I mounted the 7" midwoofer rigidly in free air and used the pink noise generator and SLM built into the SoundCheck 16 software to set the SPL to 94 dB at 1 m (3.27 V).

Then, I measured the distortion with the Listen microphone placed 10 cm from the dustcap. This produced the distortion curves shown in **Figure 27**. As with the Ellipticor D3404/552000, third-order harmonic distortion was extremely low.

For the final test, I used SoundCheck 16 to get a 2.83 V/1 m 18WE/4542T00 impulse response and imported that data into Listen's SoundMap Time/Frequency software. **Figure 28** shows the resulting CSD waterfall plot. **Figure 29** shows the Wigner-Ville (for its better low-frequency performance) plot.

The test results for this uniquely configured transducer indicate very solid performance. I plan to use both Ellipticor drivers in an upcoming project, and I can't wait to hear the results! For more information about these and other Scan-Speak transducers, visit www.scan-speak.dk. ***VC***

Submit Samples to Test Bench

Test Bench is an open forum for OEM driver manufacturers in the loudspeaker industry. OEMs are invited to submit samples to *Voice Coil* for inclusion in the monthly Test Bench column. Driver samples can include transducers for home audio, car audio, pro sound, multimedia, or musical instrument applications. While many of the drivers featured in *Voice Coil* come from OEMs that have a stable catalog of products, this is not a necessary criterion. Any woofer, midrange, or tweeter an OEM manufacturer feels is representative of its work, is welcome to send samples. However, contact *Voice Coil* Editor Vance Dickason, prior to submission to discuss which drivers are being submitted. Send samples in pairs and addressed to:

Vance Dickason Consulting
333 S. State St., #152
Lake Oswego, OR 97034
(503-557-0427)
vdconsult@comcast.net

All samples must include any published data on the product, patent information, or any special information necessary to explain the functioning of the transducer. This should include details regarding the various materials used to construct the transducer (e.g., cone material, voice coil former material, and voice coil wire type). For woofers and midrange drivers, please include the voice coil height, gap height, RMS power handling, and physically measured Mmd (complete cone assembly including the cone, surround, spider, and voice coil with 50% of the spider, surround and lead wires removed).