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Test Bench
By Vance Dickason

Two New Illuminator Woofers from ScanSpeak

Following up last month's Test Bench introduction of three new Illuminator tweeters from ScanSpeak, this month's column features two new Illuminator woofers: the 15WU/4741T00 5.25″ midwoofer, and the 18WU/474T00 6.5″ midwoofer.

The new 15WU and 18WU are not replacements for the Revelator 15W and 18W products, but the bar is set fairly high for these new drivers to meet or exceed. That said, the new midwoofers look very impressive, both cosmetically and feature-wise. The first thing you will notice is the very unusual cone configuration. Like the Revelator woofers, ScanSpeak chose to stick with a paper formula rather than move on to some other exotic cone formulation. Paper cones, properly executed, still represent one of the most musical timbres available.

One of the distinguishing features of the Revelator woofers was the orange slice cut on the cone surface that was glued back together to mute cone modes. The method used to achieve a similar effect for the Illuminator cones comes in the form of a shaped impression embossed into the front and back of the cone. While the information wasn't available to me when this was being written, I'm guessing that this is two lightweight paper cones glued and pressed together, with the embossed pattern rotated 45° on the rear cone. That, along with the curvilinear shape and the turned down outer cone edge of both the 15WU and 18WU woofers, yields a very stiff cone. Both drivers have the same 1.875″ diameter convex paper dustcap.

The next most apparent change is an entirely new proprietary cast frame for both Illuminator woofers. This is a very "open" frame with all areas above and below as open for cooling as could be possible. The frame is also designed to accommodate the neodymium ring magnet underhung motors.

Both drivers utilize what appears to be the exact same motor structure, which means the same 42mm diameter four layer voice coil wound with round wire on a polyimide vented former. Both have the same Re of 3.2Ω, 6Tm Bl, Le = 0.5mH, gap height of 20mm and voice coil length of 8mm. In terms of compliance, both drivers use NBR rubber surrounds and flat cloth spiders, 4.5″ diameter for the 6.5″ 18WU and 3.5″ diameter for the 15WU. And last, both terminate to custom molded terminal block with gold terminals.

15WU/4741T00

Starting with the 15WU (***Photo 1***), I commenced analysis using the LinearX LMS analyzer and VIBox to produce

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PHOTO 1: 15WU.

both voltage and admittance (current) curves with the driver clamped to a rigid test fixture in free-air at 0.3V, 1V, 3V, 6V, and 10V. As has become the protocol for Test Bench testing, I no longer use a single added mass measurement and instead used actual measured mass, but the manufacturer's measured Mmd data. At this point I discarded the 10V curves as being too nonlinear for the curve fitting algorithm to resolve. Next, I post-processed the remaining eight 550 point stepped sine wave sweeps for each 15WU sample and divided the voltage curves by the current curves (admittance) to derive impedance curves, phase added by the LMS calculation method, and along with the accompanying voltage curves, imported to the LEAP 5 Enclosure Shop software.

Because most Thiele/Small data provided by OEM manufacturers is being produced using either a standard method or the LEAP 4 TSL model, I additionally produced a LEAP 4 TSL model using the 1V free-air curves. I selected the complete data set, the multiple voltage impedance curves for the LTD model (see ***Fig. 1*** for the 1V free-air impedance curve), and the 1V impedance curve for the TSL model in the transducer derivation menu in LEAP 5 and produced the parameters for the computer box simulations. ***Table 1*** compares the LEAP 5 LTD and TSL data and factory parameters for both 15WU samples.

LEAP parameter calculation results for the 15WU were reasonably close to the factory data, with a somewhat lower Vas for the measured data compared to the factory data. However, this was more than close enough to proceed setting up computer enclosure simulations using the LEAP LTD parameters for Sample 1. I set up two box simulations, one sealed and one vented. This resulted in a 0.09ft^3 sealed box with 50% fiberglass fill material, and a 0.13ft^3 Qb3 vented enclosure with 15% fiberglass fill material and tuned to 50Hz.

Table 1: ScanSpeak 15WU/4741T00 Woofer

	TSL model		LTD model		Factory
	sample 1	sample 2	sample 1	sample 2	
F_S	36.5Hz	37.1Hz	34.2Hz	34.9Hz	34Hz
R_{EVC}	3.17	3.20	3.17	3.20	3.2
Sd	0.0087	0.0087	0.0087	0.0087	0.0092
Q_{MS}	3.69	3.63	3.56	3.48	3.47
Q_{ES}	0.30	0.30	0.28	0.29	0.25
Q_{TS}	0.28	0.28	0.27	0.26	0.23
V_{AS}	15.6 ltr	15.1 ltr	17.9 ltr	17.2 ltr	20.1 ltr
SPL 2.83V	85.8dB	85.9dB	85.9dB	85.9dB	85.9dB
X_{MAX}	6.0mm	6.0mm	6.0mm	6.0mm	6.0mm

Figure 2 displays the results for the 15WU in the sealed and vented boxes at 2.83V and at a voltage level high enough to increase cone excursion to Xmax + 15% (6.9mm). This produced a F3 frequency of 87.6Hz with a box/driver Qtc of 0.67 for the 0.09ft^3 sealed enclosure and –3dB = 79Hz for the 0.13ft^3 vented simulation. Increasing the voltage input to the simulations until the maximum linear cone excursion was reached resulted in 106dB at 23V for the sealed enclosure simulation and 108.5dB with a 27V input level for the larger vented box (see ***Figs. 3*** and ***4*** for the 2.83V group delay curves and the 23/27V excursion

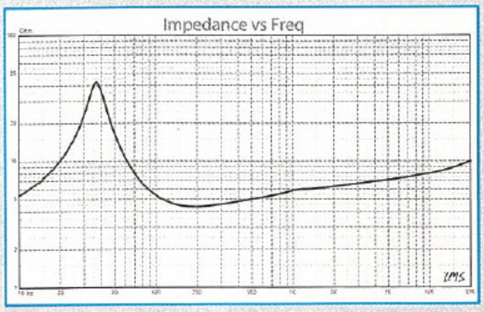

FIGURE 1: ScanSpeak 15WU/4741T00 woofer free-air impedance plot.

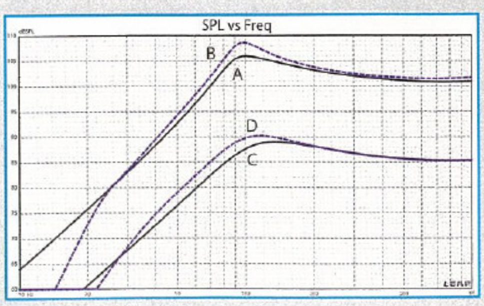

FIGURE 2: 15WU/4741T00 computer box simulations (A = sealed 1 at 2.83V; B = sealed 2 at 2.83V; C = sealed 1 at 23V; D = sealed 2 at 27V).

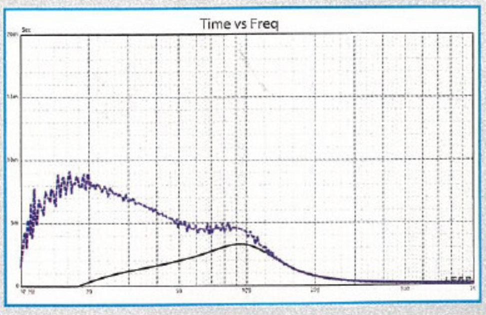

FIGURE 3: Group delay curves for the 2.83V curves in *Fig. 2*.

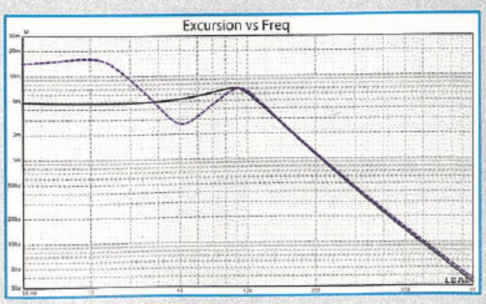

FIGURE 4: Cone excursion curves for the 23/27V curves in *Fig. 2*.

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curves).

Klippel analysis for the ScanSpeak 5.25″ woofer (our analyzer is provided courtesy of Klippel GmbH), performed by Pat Turnmire, Red Rock Acoustics (author of the SpeaD and RevSpeaD software), produced the Bl(X), Kms(X) and Bl and Kms symmetry range plots given in ***Figs. 5-8***. 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 driver project, Red Rock Acoustics can provide Klippel analysis of most any driver for a nominal fee of \$100 per unit (www.redrockacoustics.com).

The Bl(X) curve for the 15WU (***Fig. 5***) is very broad and symmetrical, an affectation of the underhung configuration. In the Bl symmetry plot (***Fig. 6***), this curve shows a

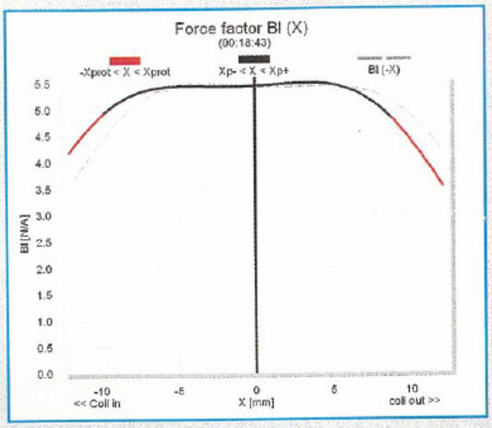

FIGURE 5: Klippel Analyzer Bl (X) curve for the 15WU/4741T00.

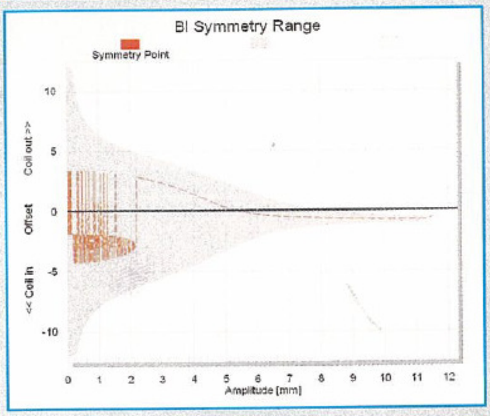

FIGURE 6: Klippel Analyzer Bl symmetry range curve for the 15WU.

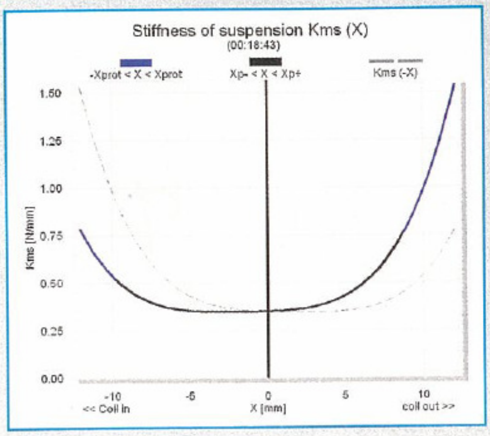

FIGURE 7: Klippel Analyzer mechanical stiffness of suspension Kms (X) curve for the 15WU/4741T00.

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coil forward offset at the rest position (obviously, the analyzer was having trouble resolving this below 3mm) that goes to 0mm offset at about 5mm of excursion and then stays constant throughout the operating range of the driver with a minor rearward (coil-in) offset of 1mm. ***Figures 7*** and ***8*** show the Kms(X) and Kms symmetry range curves for the 15WU. The Kms(X) curve has some minor asymmetry in both directions, but with a coil-in offset of about 2.75mm at the rest position decreasing to 2mm coil-in offset at the physical Xmax position.

Displacement limiting numbers calculated by the Klippel analyzer for the 15WU were XBl at 82% Bl = 8.7mm and for XC at 75% Cms minimum was 5.7mm, which means that the compliance is the most limiting factor for prescribed distortion level of 10%. ***Figure 9*** gives the inductance curves Le(X). Inductance will typically increase in the rear direction from the zero rest position as the voice coil covers more pole area, but the slope of this curve decreases in the rear direction, which is a result of the copper shorting sleeve that you can see at the top of the motor system.

Next I mounted the 15WU/4741T00 woofer in an enclosure which had a 13″ × 6″ baffle and was filled with

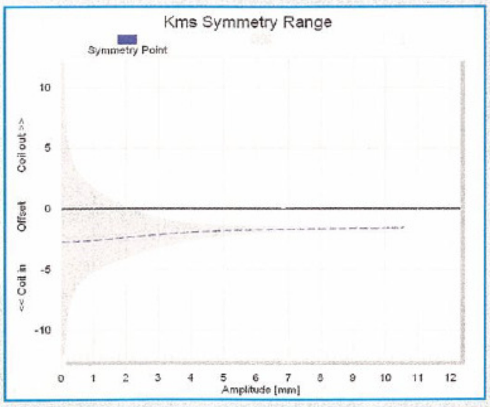

FIGURE 8: Klippel Analyzer Kms symmetry range curve for the 15WU.

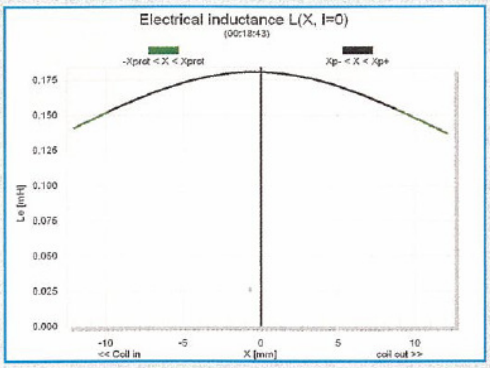

FIGURE 9: Klippel Analyzer Le(X) curve for the 15WU/4741T00.

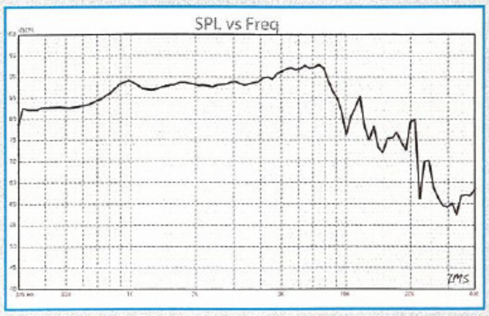

FIGURE 10: ScanSpeak 15WU/4741T00 on-axis frequency response.

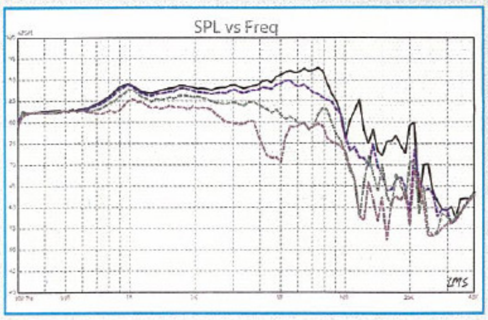

FIGURE 11: ScanSpeak 15WU/4741T00 on- and off-axis frequency response.

FIGURE 12: ScanSpeak 15WU/4741T00 two-sample SPL comparison.

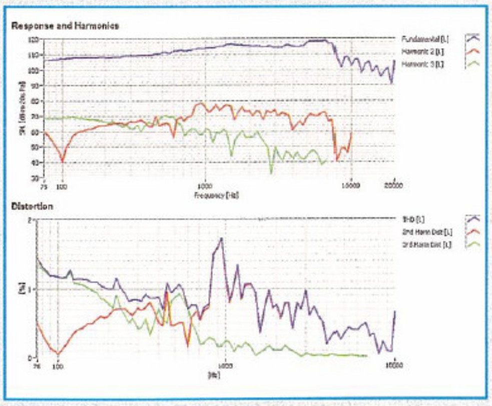

FIGURE 13: ScanSpeak 15WU/4741T00 SoundCheck distortion plot.

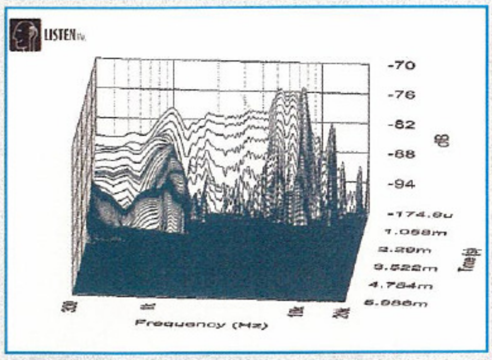

FIGURE 14: ScanSpeak 15WU/4741T00 SoundCheck CSD waterfall plot.

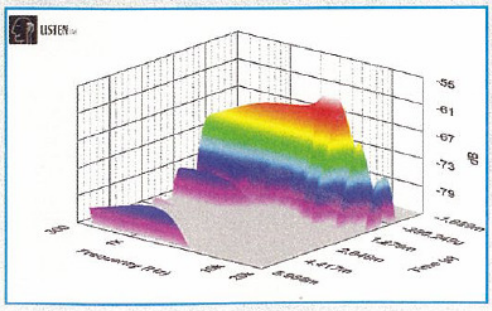

FIGURE 15: ScanSpeak 15WU/4741T00 SoundCheck Wigner-Ville plot.

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damping material (foam) and then measured the DUT on- and off-axis from 300Hz to 20kHz frequency response at 2.83V/1m using the LinearX LMS analyzer set to a 100 point gated sine wave sweep. ***Figure 10*** gives the on-axis response indicating a smoothly rising response to about 7.5kHz, with a 2-3dB peak centered on 950Hz. ***Figure 11*** displays the on- and off-axis frequency response at 0, 15, 30, and 45°. -3dB at 30° with respect to the on-axis curve occurs at 2.5kHz, so a crosspoint in that vicinity should be optimal. And finally, ***Fig. 12*** gives the two-sample SPL comparisons for the 5.25″ ScanSpeak driver, showing a very close match throughout the operating range.

For the remaining battery of tests, I employed the Listen Inc. SoundCheck analyzer (courtesy of Listen Inc.) to measure distortion and generate time frequency plots. For the distortion measurement, I mounted the woofer rigidly in free-air, and set the SPL to 94dB at 1m using a noise stimulus, and then measured the distortion with the Listen Inc. microphone placed 10cm from the dust cap. This produced the distortion curves shown in ***Fig. 13***. I then used SoundCheck to get a 2.83V/1m impulse response for this driver and imported the data into Listen Inc.'s SoundMap Time/Frequency software. The resulting CSD waterfall plot is given in ***Fig. 14*** and the Wigner-Ville (for its better low-frequency performance) plot in ***Fig. 15***.

18WU/474T00

With analysis on the 15WU completed, I performed an identical group of tests on the ScanSpeak 6.5″ 18WU (***Photo 2***). Again, I employed the LinearX LMS analyzer and VIBox to produce both voltage and admittance (current) curves with the driver clamped to a rigid test fixture in free-air at 0.3V, 1V, 3V, 6V, and 10V. I post-processed the ten 550 point stepped sine wave sweeps for each 18WU sample and divided the voltage curves by the current curves (admittance) to produce impedance curves, phase added using LMS calculation method, and along with the accompanying voltage curves, uploaded to the LEAP 5 Enclosure Shop software.

PHOTO 2: 18WU.

Besides the LEAP 5 LTD model results, I additionally produced a LEAP 4 TSL model set of parameters using just the 1V free-air curves. I selected the final data, which includes the multiple voltage impedance curves for the LTD model (see ***Fig. 16*** for the 1V free-air impedance curve) and the 1V impedance curve for the TSL model, and produced the parameters in order to perform the computer box simulations. ***Table 2*** compares the LEAP 5 LTD and TSL data and factory parameters for both 18WU samples.

Table 2: ScanSpeak 18WU/4741T00 Woofer

	TSL model sample 1	sample 2	LTD model sample 1	sample 2	Factory
F_S	36.0Hz	40.0Hz	36.0Hz	37.0Hz	30Hz
R_{EVC}	3.18	3.20	3.18	3.20	3.2
Sd	0.0152	0.0152	0.0152	0.0152	0.0154
Q_{MS}	4.00	4.59	4.16	4.43	3.56
Q_{ES}	0.41	0.43	0.40	0.36	0.32
Q_{TS}	0.37	0.39	0.37	0.36	0.29
V_{AS}	33.7 ltr	39.0 ltr	38.5 ltr	37.0 ltr	49.9 ltr
SPL 2.83V	87.7dB	87.9dB	87.5dB	88.0dB	87.2dB
X_{MAX}	6.0mm	6.0mm	6.0mm	6.0mm	6.0mm

LEAP parameter calculation results for the 18WU appear to be very different from the factory data. However, the Fs/Qt ratios were very close when I programmed the factory data into a sealed box simulation with the same volume as I used for the LEAP calculated LTD parameters. F3 was 60Hz for the factory data compared to F3 = 61Hz for the LEAP 5 LTD parameters. Given this, I proceeded setting up computer enclosure simulations using the LEAP LTD parameters for Sample 1. I set up two box simulations, one sealed and one vented. For the closed box simulation I used a 0.44ft^3 enclosure with 50% fiberglass fill material, and for the vented box, a 0.71ft^3 Qb3 vented enclosure with 15% fiberglass fill material and tuned to 37Hz.

Figure 17 illustrates the results for the 18WU in the sealed and vented boxes at 2.83V and at a voltage level high enough to increase cone excursion to Xmax + 15% (6.9mm). This yielded a F3 = 61Hz with a box/driver Qtc of 0.71 for the 0.44ft^3 sealed enclosure and –3dB = 52Hz for the 0.71ft^3 vented simulation. Increasing the voltage input to the simulations until the maximum linear cone excursion was reached resulted in 105dB at 16V for the sealed enclosure simulation and 107.5dB with an

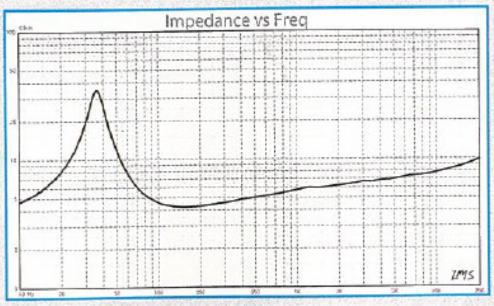

FIGURE 16: ScanSpeak 18WU/4741T00 free-air impedance plot.

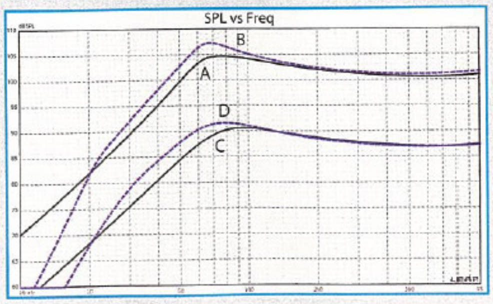

FIGURE 17: 18WU/4741T00 computer box simulations (A = vented at 2.83V; B = vented at 2.83V; C = vented at 16V; D = vented at 18V).

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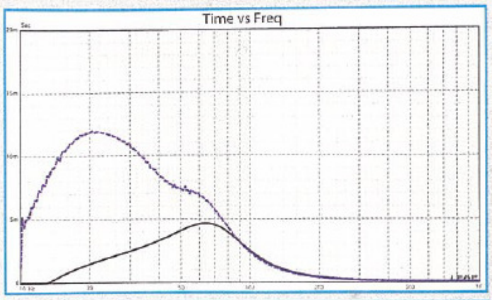

FIGURE 18: Group delay curves for the 2.83V curves in *Fig. 17.*

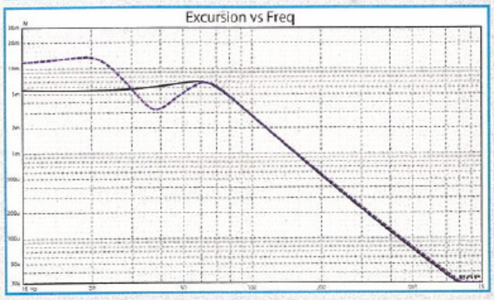

FIGURE 19: Cone excursion curves for the 16/18V curves in *Fig. 17.*

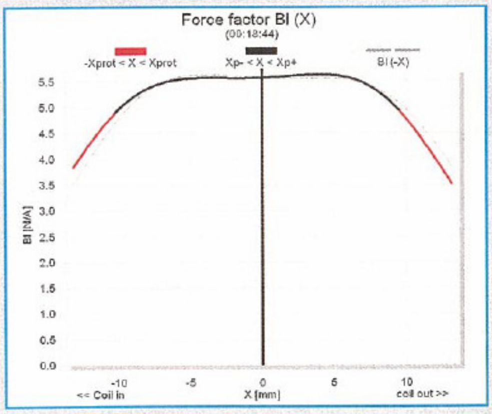

FIGURE 20: Klippel analyzer Bl (X) curve for the 18WU/4741T00.

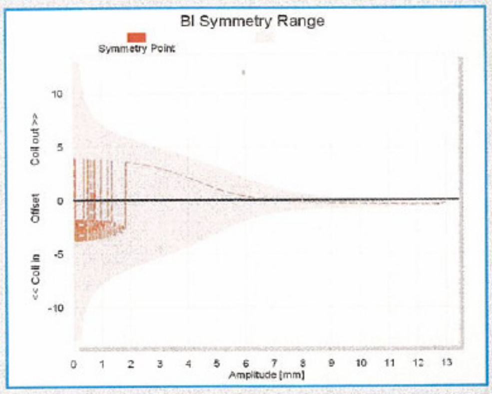

FIGURE 21: Klippel analyzer Bl symmetry range curve for the 18WU.

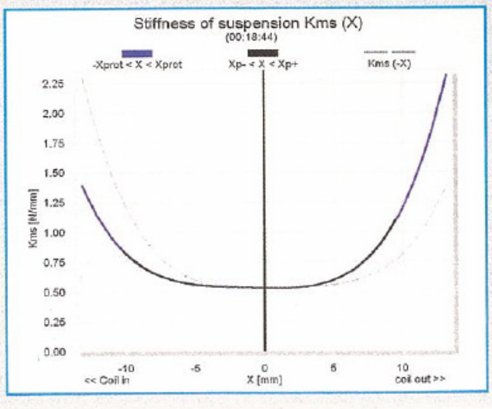

FIGURE 22: Klippel Analyzer mechanical stiffness of suspension Kms (X) curve for the ScanSpeak 18WU/4741T00.

18V input level for the larger vented box (see ***Figs. 18*** and ***19*** for the 2.83V group delay curves and the 16/18V excursion curves).

Klippel analysis for the ScanSpeak 6.5″ woofer produced the Bl(X), Kms(X) and Bl and Kms symmetry range plots given in ***Figs. 20-23***. The Bl(X) curve (***Fig. 20***) is very broad and symmetrical, and like the 15WU, an affectation of the underhung configuration. In the Bl symmetry plot (***Fig. 21***), this curve shows a coil forward offset at the rest position (obviously, the analyzer was again having trouble resolving this below 3mm) that goes to 0.5mm offset at about 6mm of excursion and then stays constant throughout the remainder of the operating range. ***Figures 22*** and ***23*** give the Kms(X) and Kms symmetry range curves for the 18WU. The Kms(X) curve has some minor asymmetry in both directions, but with a coil-out offset of about 1mm at the rest position decreasing to 1mm coil-in offset at the physical Xmax position.

Displacement limiting numbers calculated by the Klippel analyzer were XBl at 82% Bl = 9.5mm and for XC at 75% Cms minimum was 6.4mm, which, like the 15WU, means that for the 18WU woofer, the compliance is the most limiting factor for prescribed distortion level of 10%. ***Figure 24*** gives the inductance curves Le(X) for the 18WU. This is also very similar to the 15WU, with a decreasing inductance as the coil moves inward, the result of the copper shorting sleeve in this motor system.

Following the Klippel testing, I mounted the 18WU/4741T00 woofer in an enclosure which had a 17″ × 8″ baffle and was filled with damping material (foam) and then measured the DUT on- and off-axis from 300Hz to 20kHz frequency response at 2.83V/1m using a 100-point

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gated sine wave sweep. ***Figure 25*** gives the on-axis response displaying a very smooth rising response to about 7kHz, with a 2-3dB peak centered on 3.5Hz.

Figure 26 has the on- and off-axis frequency response at 0, 15, 30, and 45°. -3dB at 30° with respect to the on-axis curve occurs at 2.3kHz, so a crosspoint in that vicinity should be fine, if not somewhat low for the typical 6.5″ driver. And finally, ***Fig. 27*** gives the two-sample SPL comparisons for the 6.5″ ScanSpeak driver, showing a close match up to 2kHz, with about 1dB variations above that frequency.

For the last group of tests, I employed the Listen Inc. SoundCheck analyzer (courtesy of Listen Inc.) to measure distortion and generate time frequency plots. Setting up for the distortion measurement consisted of mounting the woofer rigidly in free-air, and the SPL set to 94dB at 1m using a noise stimulus (SoundCheck has a software generator and SPL meter as two of its utilities), and then the distortion measured with the Listen Inc. microphone placed 10cm from the dust cap. This produced the distortion curves shown in ***Fig. 28***.

Last, I employed the SoundCheck analyzer to get a 2.83V/1m impulse response for this driver and imported the data into Listen Inc.'s SoundMap Time/Frequency software. The resulting CSD waterfall plot is given in ***Fig. 29*** and the Wigner-Ville (for its better low-frequency performance) plot in ***Fig. 30***. For more information on these and the other new ScanSpeak Illuminator drivers, visit www.tymphany.com. **VC**

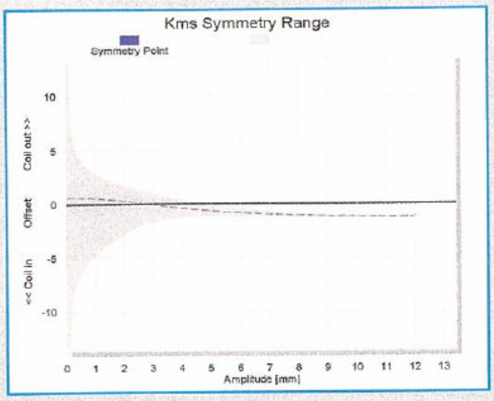

FIGURE 23: Klippel analyzer Kms symmetry range curve for the 18WU.

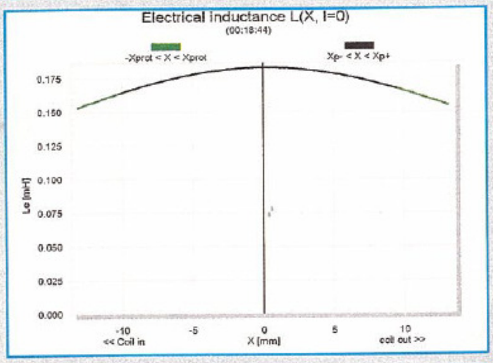

FIGURE 24: Klippel Analyzer Le(X) curve for the ScanSpeak 18WU/4741T00.

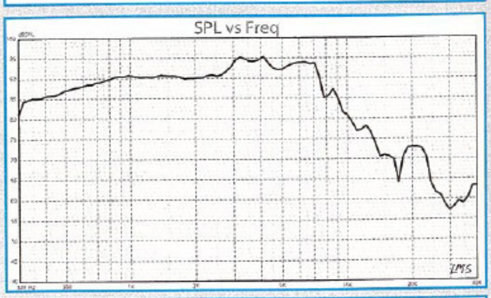

FIGURE 25: ScanSpeak 18WU/4741T00 on-axis frequency response.

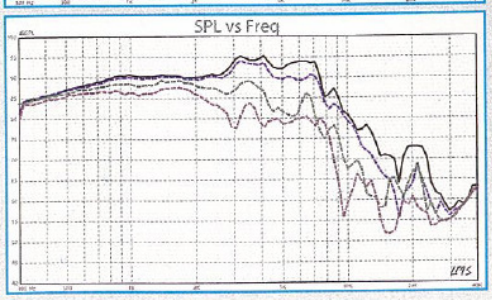

FIGURE 26: ScanSpeak 18WU/4741T00 on- and off-axis frequency response.

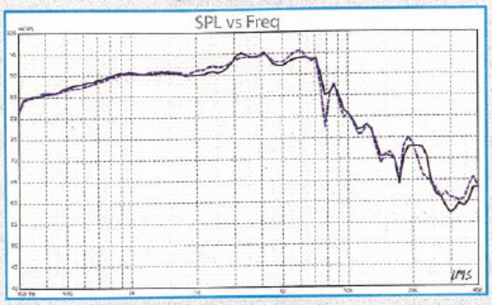

FIGURE 27: ScanSpeak 18WU/4741T00 two-sample SPL comparison.

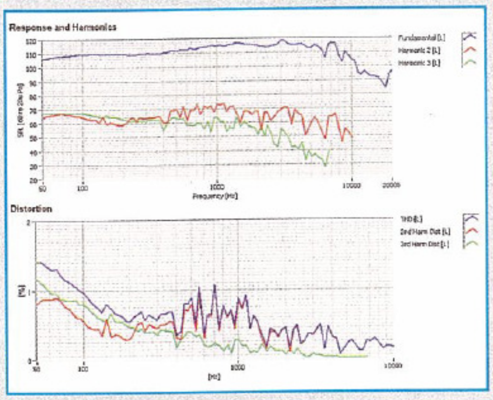

FIGURE 28: ScanSpeak 18WU/4741T00 SoundCheck distortion plots.

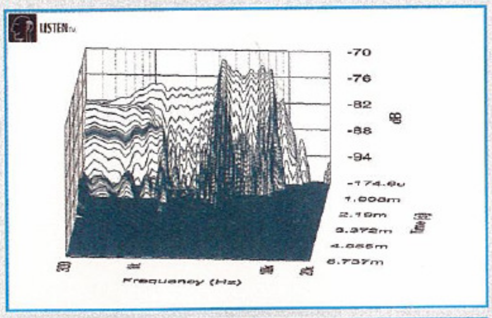

FIGURE 29: ScanSpeak 18WU/4741T00 SoundCheck CSD waterfall plot.

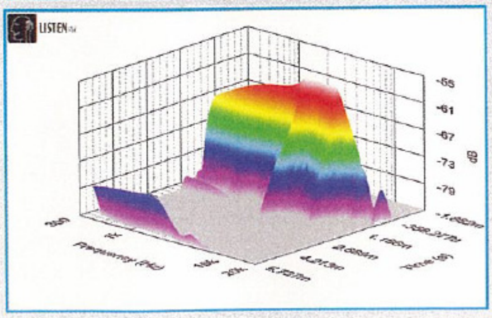

FIGURE 30: ScanSpeak 18WU/4741T00 SoundCheck Wigner-Ville plot.