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ADVANCING THE EVOLUTION OF AUDIO TECHNOLOGY

Speaker Focus Edition!

Fresh From the Bench

PureAudioProject

Trio15 Heil AMT Speakers

**By Oliver A. Masciarotte
and Kent Peterson**

You Can DIY!

The AXL Dipole Loudspeaker

By George Ntanavaras

The Echelons

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**Purifi Audio: A Straight Wire
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R&D Stories

**Dealing with
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**Listening to Modeled
Amp Designs Using LTspice**

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Show Report

High End 2019

**Groundbreaking Evolution,
Surprises, and Great Demos
in Munich!**

By Ward Maas





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Accelerating Innovation in Loudspeaker Development



There's a really good article mix for this 2019 Speaker Focus edition of *audioXpress*. On the DIY side, our readers will find high-quality projects that show a strong emotional connection with speaker building. But more importantly, these are DIY projects that show how builders, much like all speaker designers, thrive to find something new: a new challenge, a new design, experiment, or technical innovation. There's always a threshold that needs to be crossed. And pretty much that's what happening generically in today's audio industry, where speaker design benefits from a lot of new exciting possibilities.

We are living in one of the most significant category expansions ever with the introduction of "smart speaker" designs, benefiting from an impressive new class of highly efficient amplifiers, closely integrated with digital signal processing, and extremely efficient drivers. Of course, the "smart" part implies a close integration with sensors—including microphones for signal feedback—to enable things such as automatic response adjustments and room correction. Naturally, in the last five years these applications have turned heads and many companies in different areas have started to look at ways to quickly market new developments that can fuel the category even more.

With so much investment and innovation, speaker builders are benefiting from completely new tools and in particular, new materials. Oxeon of Sweden has recently introduced Thin Ply Carbon Diaphragms, a new category based on its TeXtreme advanced composite material created by arranging layers of carbon fiber in an optimized manner. Materials such as Truextent, in current market conditions, have generated so much interest that the first examples of actual drivers are now reaching the market. SB Acoustics is now using TeXtreme carbon diaphragms in products such as the Satori TW29TXN-4 tweeter, which compares favorably with beryllium alternatives at a much more competitive price point. There's also a (still unnamed) new woofer with Advanced TeXtreme cone and slow damping rubber surround, which surprises everyone who listens to it. This is not just a small improvement. In fact, SB Acoustics built a pair of demo speakers for the 2019 High End show in Munich, and impressed visitors so much that the speakers gained "best of show" classifications. So, very soon, expect to find new tweeters, compression drivers, midranges, and full ranges using TeXtreme in the market, at a variety of price points.

Another example of the continuous research in speaker technology is illustrated by graphene products entering the market. Initially, manufacturers are targeting small transducers for headphones and microspeakers, but we wouldn't be surprised to see an uptake in extremely high-volume products (e.g., smart speakers), where the economies of scale have the potential to quickly turn logic around. That is, if the research companies working on graphene can quickly find a way to churn out high volumes. While we still don't have drivers using pure graphene diaphragms, we already have many products that are exploring its benefits, like SEAS' recent line of Excel Graphene woofers, with three models now shipping. All Excel Graphene drivers feature a graphene-coated magnesium cone, ensuring higher damping as well as the stiffness of the cone, while protecting it from corrosion. The result has exceptional high dynamic capability, delivering clean and undistorted sound suitable for the reproduction of High-Res audio material.

There are many more examples of innovations and driver optimizations from other manufacturers, but recently the industry was positively surprised with the announcements from a new Danish audio company, founded by Bruno Putzeys, Lars Risbo, and Peter Lyngdorf. Purifi Audio introduced a new Class-D "super amplifier" design, and a new woofer design with "magnitudes lower intermodulation distortion across frequency and SPL." *audioXpress* covered the Purifi presentation extensively on its website and weekly newsletter *The Audio Voice*. In this edition, Ward Maas comments on the demonstrations during the Munich show, while our technical editor, Jan Didden dives a little deeper into the measurements and theories unveiled by Putzeys and Risbo. Judge for yourself.

J. Martins

Editor-in-Chief

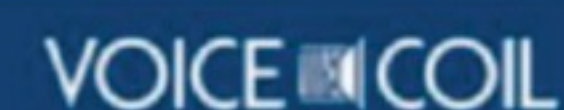
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COLUMNISTS

Vance Dickason has been working as a professional in the loudspeaker industry since 1974. He is the author of *Loudspeaker Design Cookbook*—which is now in its seventh edition and published in English, French, German, Dutch, Italian, Spanish, and Portuguese—and *The Loudspeaker Recipes*. Vance is the editor of *Voice Coil: The Periodical for the Loudspeaker Industry*, a monthly publication. Although he has been involved with publishing throughout his career, he still works as an engineering consultant for a number of loudspeaker manufacturers.

Mike Klasco is the president of Menlo Scientific, a consulting firm for the loudspeaker industry, located in Richmond, CA. He is the organizer of the Loudspeaker University seminars for speaker engineers. Mike specializes in materials and fabrication techniques to enhance speaker performance.

Dr. Richard Honeycutt fell in love with acoustics when his father brought home a copy of Leo Beranek's landmark text on the subject while Richard was in the ninth grade. Richard is a member of the North Carolina chapter of the Acoustical Society of America. Richard has his own business involving musical instruments and sound systems. He has been an active acoustics consultant since he received his PhD in electroacoustics from the Union Institute in 2004. Richard's work includes architectural acoustics, sound system design, and community noise analysis.

Steve Tatarunis has been active in the loudspeaker industry since the late 1970s. His areas of interest include product development and test engineering. He is currently a support engineer at Listen, in Boston, MA, where he provides front-line technical support to the SoundCheck test system's global user base.

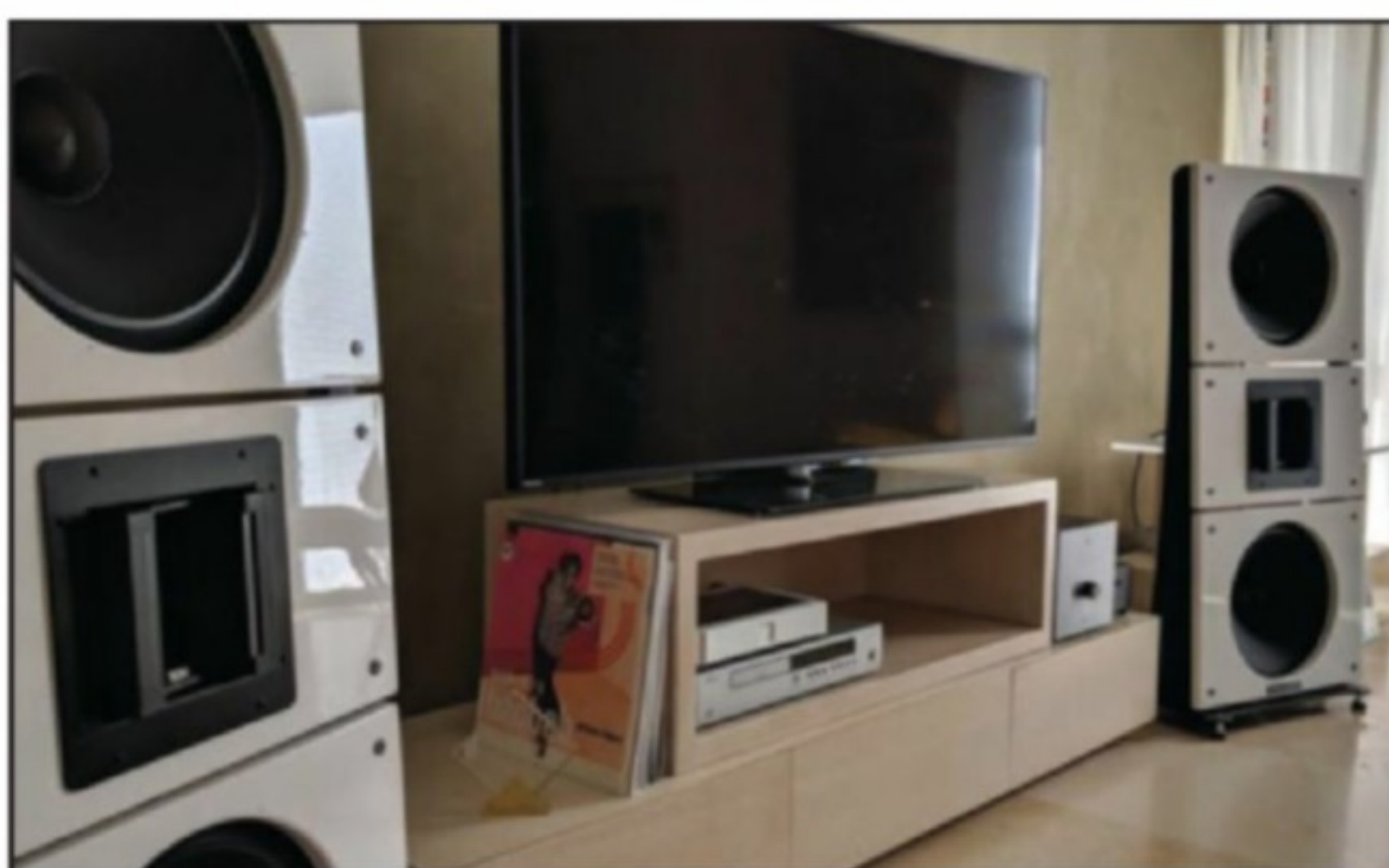
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By George Ntanavaras

George Ntanavaras tackles his next speaker project, which he dubbed the AXL loudspeaker. His latest creation is an open-baffle, four-way active loudspeaker that he has dedicated to one of his longtime role models, Siegfried Linkwitz.

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Go for the State-of-the-Art in DIY!

By Dan Neubecker

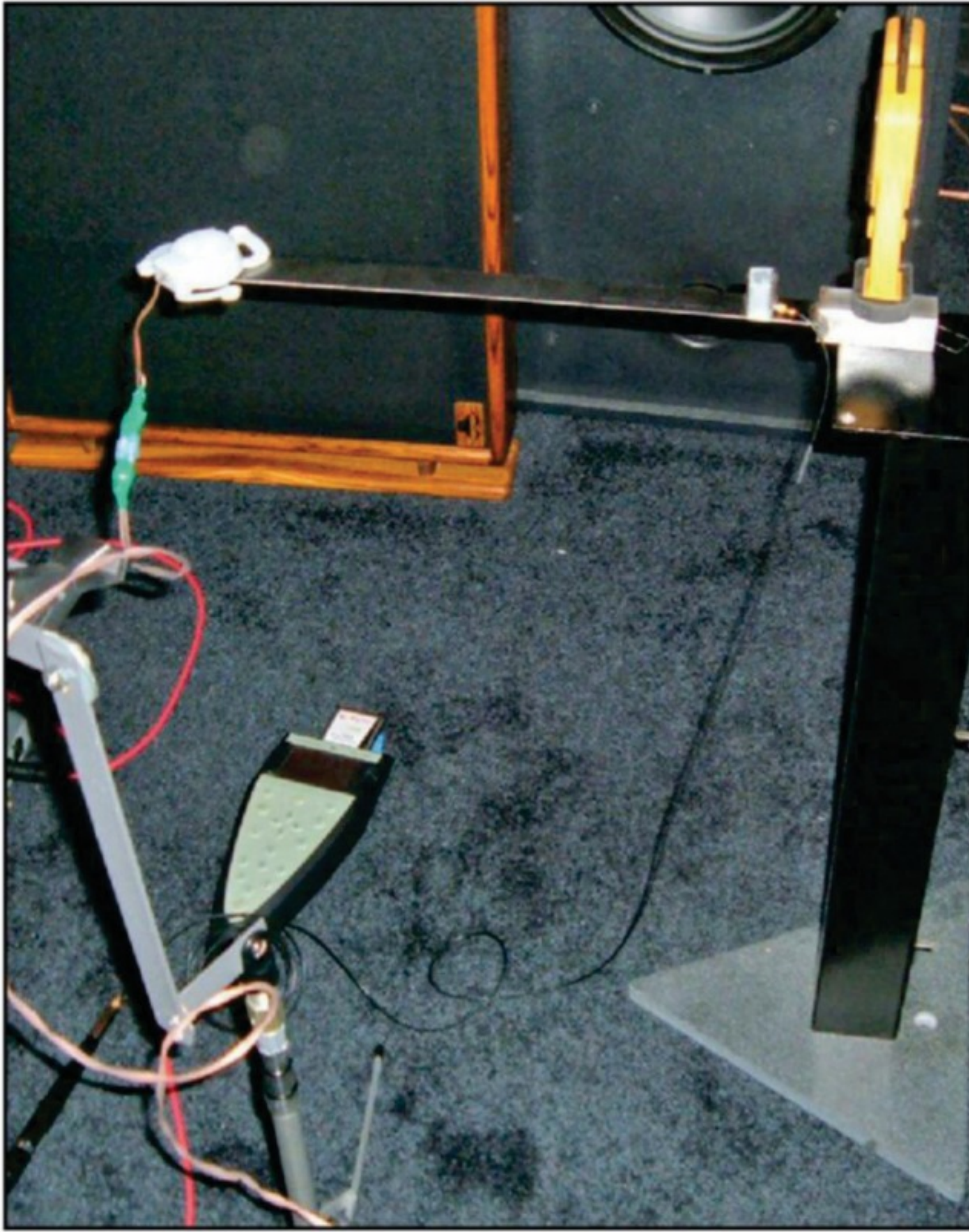
Can you really design and build a top-notch speaker in your garage? In this article, Dan Neubecker illustrates that it is possible, particularly if you are passionate about both audio and woodworking. DIY speaker building can be a compelling adventure, one that consumes much of your free time, but also brings ample rewards that include years of enjoyment and the satisfaction of having created something yourself.

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Groundbreaking Evolution, Surprises, and Great Demos in Munich

By Ward Maas

The High End Show contains just about everything that is available in high-end audio. There are so many manufacturers and so many “novelties” on display, it is often difficult to know where to begin. But, as in past years, Ward Maas dove in and is now sharing his findings.

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By Oliver A. Masciarotte and Kent Peterson

Oliver Masciarotte introduces readers to PureAudioProject and its founder Ze’ev Schlik before detailing his experience with the Trio15 Heil AMT speakers, which feature the ESS Heil Air Motion Transformer 1. Kent Peterson, of Warkwyn, then puts the Trio15 to the test to see if they sound as good as they look.

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A Straight Wire to the Soul of Music

By Jan Didden and J. Martins

As *audioXpress* previously reported, Purifi Audio is a new venture involving several audio industry veterans. The Netherlands Audio Engineering Society (AES) section invited two of the company’s founders, Bruno Putzeys and Lars Risbo, for a technical update on their plans, and our Technical Editor Jan Didden attended and reports. J. Martins also shares a bit of the interview that he conducted with some of the principals of Purifi Audio.

52 Good Vibrations (Part 2) The Basic Principles of Unwanted Vibrations

By Norman Varney

When we play back audio, we only want to hear sound waves created from the electro-mechanical vibrations produced by the loudspeaker. These are good vibrations. But what happens when there are bad vibrations? In Part 2 of this article, Norman Varney explores ways to solve these issues using various products his company researched and provides for clients with acoustic problems.

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High End 2019

Groundbreaking Evolution, Surprises, and Great Demos in Munich



The High End Show contains just about everything that is available in high-end audio. There are so many manufacturers and so many “novelties” on display, it is often difficult to know where to begin. But, as in past years, Ward Maas dove in and is now sharing his findings.

By
Ward Maas
(The Netherlands)

During the yearly audio trade show circus, the High End in Munich stands out because everyone, every company, and every product that matters in hi-fi can be found there. With 29.000 m² available of floor space for 551 exhibitors (representing more than 2,000 different brands) from 42 countries the show was simply packed. Fortunately, on the other side of the road along the Munich Order Center (MOC) premises where the show is held, the Motorworld

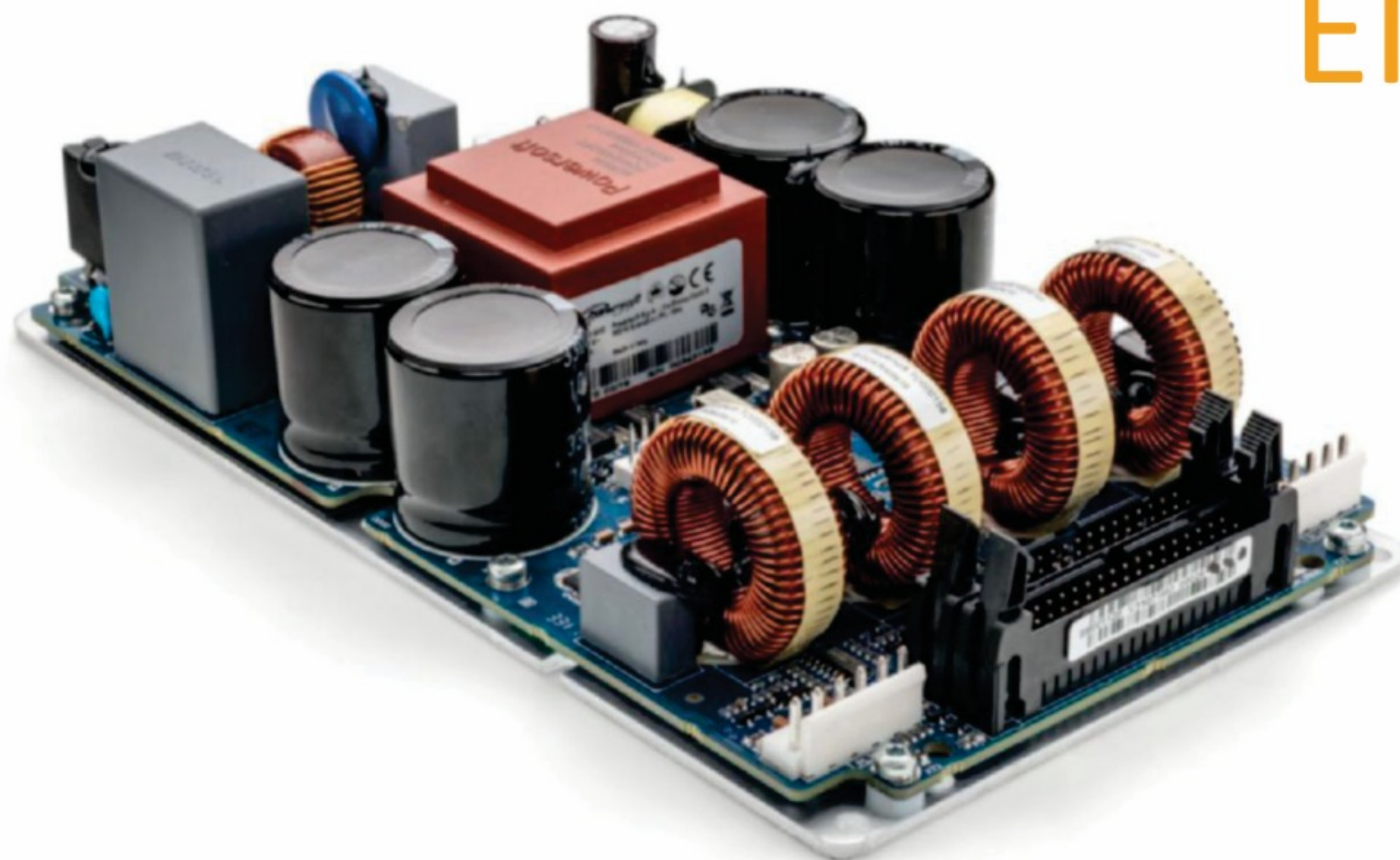
Munich event building will be opened soon. And part of that will be a convention center, where the show might find the much needed extra space for future expansion.

The Show's Introduction

The traditional press conference promoted by the High End Society, the organizers of the show, was unusually vibrant this year (see **Photo 1**). They said goodbye to the classic formula of parading the entire management team on stage, where dull facts and figures would be poured out to a mixed audience of German and international journalists, and the presentations were shorter and to the point. The big highlight for this year was the show's brand ambassador, an initiative the High End Society started to promote in previous years, and is now gaining traction. Usually, the ambassador is a musician who is paying a lot of attention to the audio quality of his work. This year it was Steven Wilson, the founder and creative force behind the progressive rock band Porcupine Tree, who is recently also pursuing a successful solo career and his work as producer and sound engineer (see **Photo 2**). He attended the show during the first two days,



Photo 1: The traditional Bavarian welcome.



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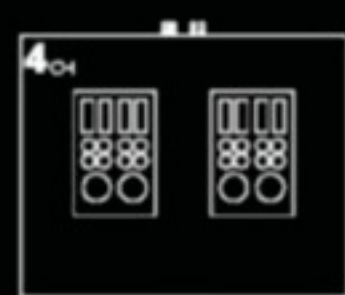


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Application Examples



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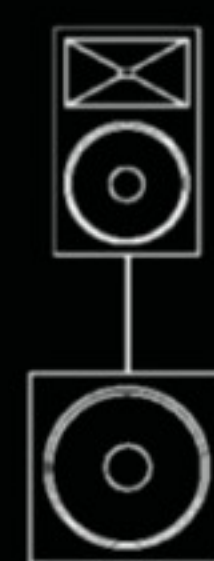
3 Way



Single / Double Sub



Monitor



Sub + Top



Sub + 2 Tops



Photo 2: The management of the High End show pictured with Steven Wilson

answered all questions during the press conference and remained available for interviews, autograph sessions, and more presentations to the public. In the press conference, Wilson discussed his view and thoughts about the work of mastering engineers who, in his opinion, should not alter in any way the artists' work. A fun and interesting exchange for an "expert" audience."

For most brands, attending the High End show in Munich is so important that the Hifideluxe show,

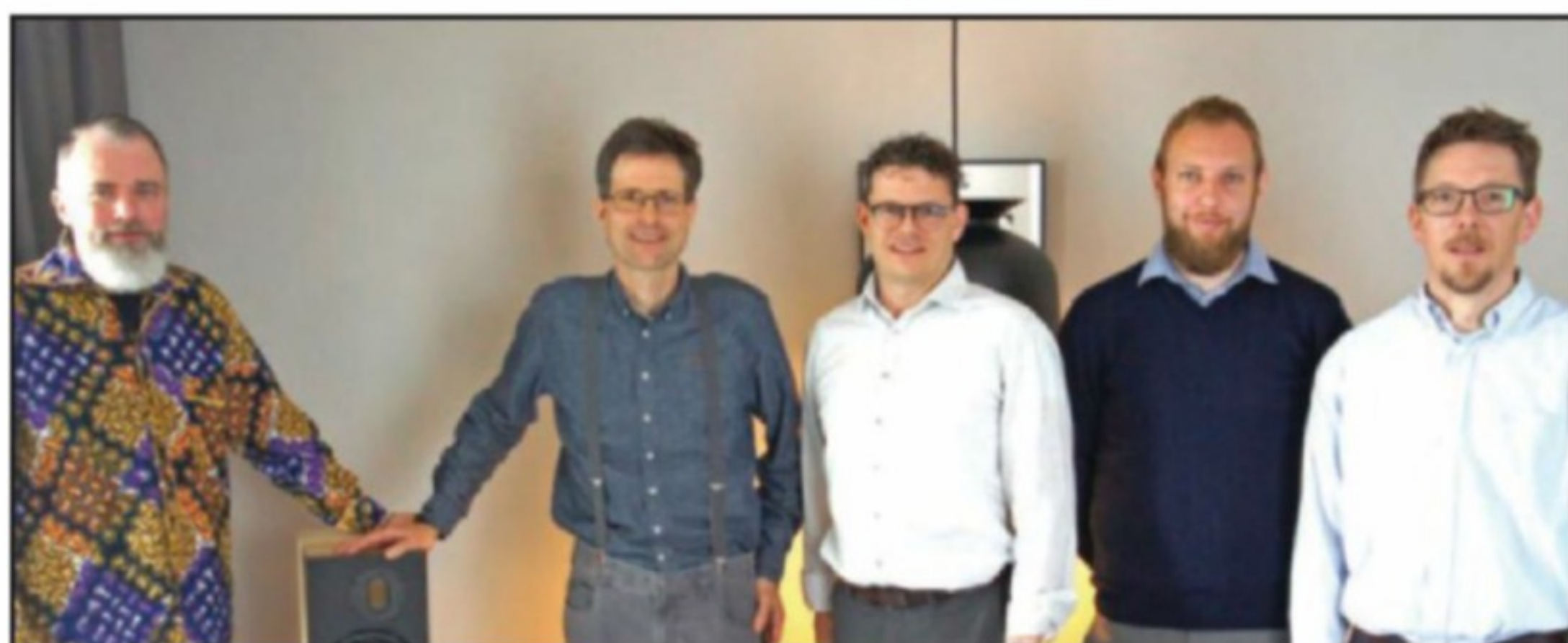


Photo 3: The Purifi Audio R&D team (left to right): Bruno Putzeys, Lars Risbo, Claus Neesgaard, Morten Halvorsen, and Carsten Tinggaard.



Photo 4: Purifi demonstrated the 400W 1ET400A Class-D amplifier module.

which is held in the nearby Marriott hotel, is not even seen as a competition and more often as a fallback location for brands that have to wait a few years before there is a place for them at the High End. The Hifideluxe, however, is often a bit more esoteric audio affair and many companies actually prefer the exclusivity and less busy environment of the excellent hotel facilities. Other companies simply rent a hotel room somewhere in Munich, and present their new products in their preferred surroundings. Therefore, it is very likely that the comments regarding the quality of the show might vary depending on which other meetings you visited, or if you attended the other show as well.

Purifi Audio

One of the meetings *audioXpress* was invited to attend during that week in Munich was with Danish company Purifi Audio (www.purifi-audio.com), which was providing a first look at their debut products. Purifi was extremely busy all throughout the duration of High End 2019, and many who visited their showroom seemed enthusiastic about what they had seen. We also think the debut of Purifi Audio was an important highlight for the show. After all, the names behind Purifi are heavyweights in today's audio industry: Bruno Putzeys, Claus Neesgaard, Lars Risbo, Kim Madsen, Carsten Tiggaard, Søren Poulsen, Peter Lyngdorf and Morten Halvorsen (see **Photo 3**).

The expectations were naturally high. Purifi makes it clear on its website that they believe that it is necessary to have a deep understanding of a problem before attempting to solve it. They do that by creating mathematical models, doing simulations and building prototypes. That circle of understanding defines them.

Purifi demonstrated the 400W 1ET400A Class-D amplifier module (see **Photo 4**) and the PTT6.5W04-01A 6.5" driver. Anyone who followed the evolution and developments in Class-D amplifiers will be undeniably aware of Bruno Putzeys' contributions in this field. With the nCore Class-D amplifier, Putzeys demonstrated the technology could be a high end contender. Putzeys mentioned a few years ago that his calculations and modeling were almost spot on. Still, the "almost" bothered him and that's why he never stopped researching. With the presented 1ET400A platform, he believes this time he is 100% correct, and that understanding what happens inside a Class-D amplifier at any moment, under any condition, makes it possible to build a new generation of amplifiers that are "mathematically exact."

The PTT6.5W04-01A driver, at first sight, despite the rather peculiar-shaped rim, doesn't look that special. But as the presentation showed, the

listening results can be convincing, as well as the measured specifications, some of which are unusual to the industry, because, as Purifi stated, the best measuring tools available for loudspeakers are not good enough and did not measure all the important parameters of their products. So, Purifi developed and perfected their own measurement tools, and believes they have the ability to create something new and can prove it. "We believe that all that matters for the sound quality can be measured although we often have to develop new measurement methods that are indicative of the subjective sound quality," they state. The datasheets that were handed out for both products show stunning results.

Of course, during our meeting with Purifi there was time for a demo. A basic loudspeaker enclosure with the prototype Purifi driver acting as a woofer and all the way to 2 kHz, handing over to the tweeter with a simple passive filter and the speaker fed from the new 1ET400A class-D amplifier.

As I was seated comfortably on a couch, it prevented me from falling over when we heard the sound of deep thumping bass and a fragile flute coming from the same speaker... It is not often that you can witness audio history in the making. I am deeply convinced that what we saw and heard that rainy morning in Munich has the potential to dramatically change the audio world. Just before the show, it was made public that NAD would be the first company to incorporate the new Class-D technology in their new products. I am convinced that they are only the first in a long list (see **Photo 5**).

After that demo, it was difficult to get back to the High End show. "After this, what else matters?" Fortunately there was more, a lot more.

The Theoretica Applied Physics BACCH-SP System

I heard there was this 3D audio system that made a great impression with the ones who were able to attend a demo. I was very fortunate that Dr. Edgar Choueiri, Professor of Applied Physics in the Mechanical and Aerospace Engineering Department of Princeton University, was holding demos at the High End show. What's more, I had the pleasure to be the reference for the audience members, who were at that particular meeting.

First, I got a pair of microphones inside my ears. Yes, just like a pair of in-ear headphones, but featuring high-quality studio microphones. With a few test tones the room acoustics and your ears are characterized. This setup goes amazingly fast. And after just a few minutes, the Theoretica Applied Physics BACCH-SP system is ready for use. The result is that, in the sweet spot, a 3D image of music



Photo 5: Purifi's amazing PTT6.5W04-01A driver prototype.



Photo 6: The BACCH-SP demo announcement we couldn't overlook...



Photo 7: Flat, flat, flat from AFI.



Photo 8: ELAC pure Alchemy.

appears contrary to “music coming from a set of stereo speakers” experience. The audio system was a MSB/Magico setup, which is extremely accurate. Normally a 3D experience tends to be a bit artificial one way or another, or as they say in Germany “Spielerei.” Well, this system sounds very natural. The used Chesky recordings got a very natural spacious dimension, which felt very natural. Like the recording sessions as someone who had been actually there said. www.theoretica.us/bacch-sp.html (see **Photo 6**).

Parts and Accessories

Also with regard to parts and accessories, there were a few companies that stood out. One of them was Asahi Kasei Microdevices (AKM), a Japanese electronic component manufacturer known for its high-quality DAC chips (www.akm.com). The High End is also attractive for technology companies such as AKM, potentially attracting new manufacturers and product developers as customers. The AK4499 is the latest “Velvet Sound/Verita” DAC, the successor of the AK4497. In mono mode the signal-to-noise ratio

is a solid 140 dB and the THD is at -124 dB. On the chip level, apparently there are still improvements possible. The expected introduction will be at the end of the year.

A bit hidden was AFI. They offer something that can be best described as a vinyl disc flattener (www.afi-record-flattener.com). The name immediately triggers these “iron waffle maker” images in my mind, but this is a very precise method to get warped vinyl discs back into the intended shape. The disc is placed between two thick cotton sheets in the flattener and the lid is closed. During a process that takes four hours the disc is “carefully relaxed” back to the desired flatness. Due to the included presets, the use is friendly and risk free. There is also an expert modus, which offers more freedom. Remarkable is the beautiful minimalistic design, which makes this record flattener a piece of equipment you do not have to hide. It definitely has a place for vinyl aficionados with large collections (see **Photo 7**).

Loudspeakers, Amps, and Preamps

At the ELAC booth (www.elac.com), we found designer Peter Madnick. Madnick is known for his work for Audio Alchemy and Constellation Audio. As ELAC bought Audio Alchemy in 2016, he was able to use the facilities and possibilities of a large company.

The results were products like the DDP-2 Preamplifier/DAC/Streaming End-Point, the DPA-2 Stereo/Mono amplifier, and the PPA-2 Phono Preamplifier. A nice discussion evolved on the topic of availability of some “audio” transistors. Don’t be afraid, ELAC still has plenty of them. Regarding ELAC loudspeakers, there was this Vela series of products with a rather clever aluminum footing, incorporating a rather ingenious bass-reflex opening. This would improve positioning. All in all, it proves that ELAC nowadays is playing on the highest level in the hi-fi market (see **Photo 8**).

Karl-Heinz Fink’s team is one of the most professional OEM hi-fi design groups in the world. To have an outlet for their own ideas (and as a marketing tool of course), they present something special every year at the High End. Professionals as they are, they make sure their demonstration room sounds great. The very well-prepared room is an example for other companies. This year, Team Fink (www.finkteam.com) presented the Borg loudspeaker, a well-tuned two-way system consisting of a 10.25” bass loudspeaker combined with a Mundorf air motion transformer (AMT). This combination sounded remarkably effortless and elegant for a large system like this. Their recommendation, with a wink, is to buy two of them (see **Photo 9**).



Photo 9: The Fink Team at work in their (very good) listening environment

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CELESTION



Photo 10: The amazing second-generation NAIM Mu-so

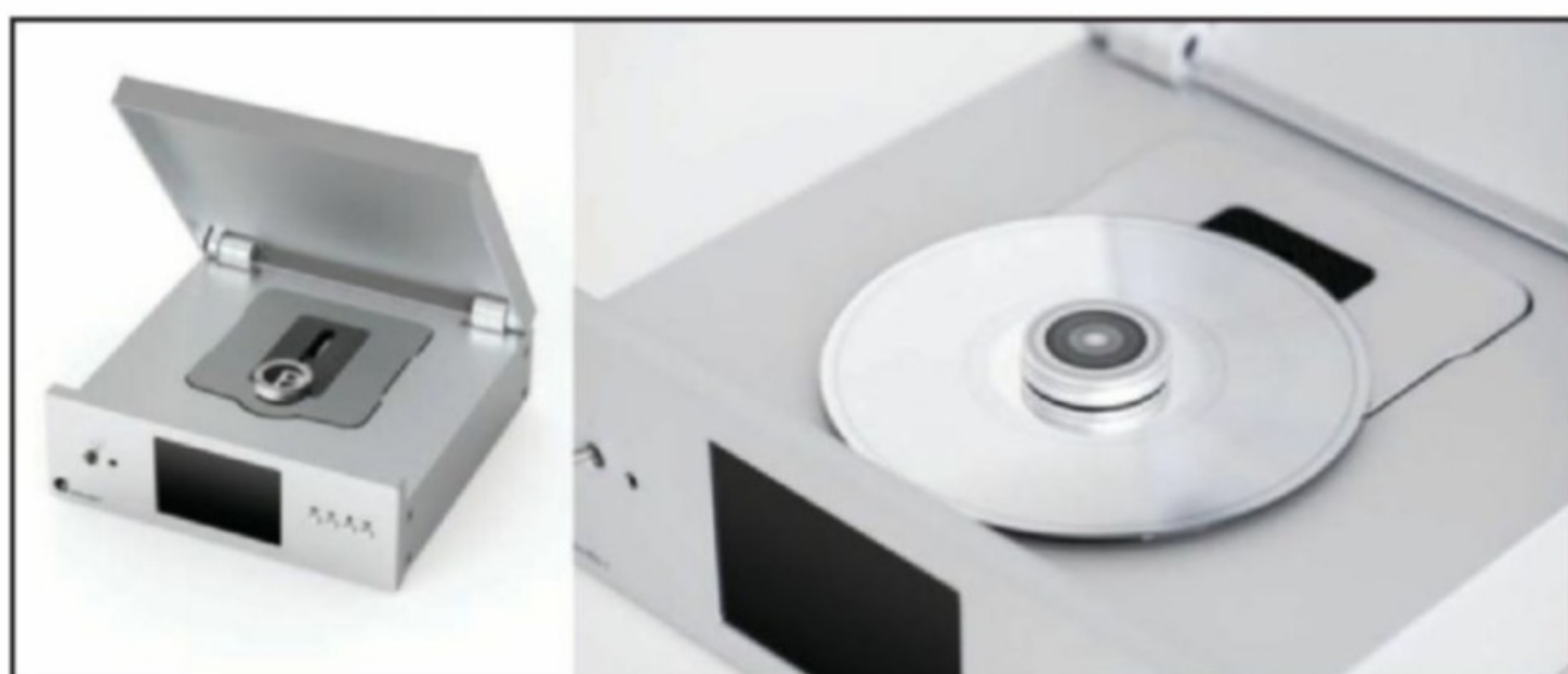


Photo 11: The new Pro-Ject CD Box RS2 T is transport-only



Photo 12: A recording session in progress at the Dynaudio Unheard studio

About the Author

Ward Maas is the owner of Pilgham Audio. He studied electronics, marketing, and amplifier design. During his career in consumer electronics, Ward worked in areas ranging from CD standardization to radio and television to personal GPS navigation. Ward has worked on an extreme low-noise magnetic cartridge preamplifier and several special amplifier products. As the CTO of "Witchworld," a theme park near Amsterdam, he also works with animatronics. He lives in Almere, Netherlands, with his wife and son.

Lyngdorf (<https://lyngdorf.com>) is one of those brands that is, one way or another, remarkably understated. The Lyngdorf products not only look brilliant, but performance and quality-wise they are just great. At Integrated Systems Europe (ISE) 2019 in Amsterdam earlier this year, Lyngdorf introduced the MXA-8400, an eight-channel amplifier (3.2 kW in total), which sets an example. This can be said about all of their products. Lyngdorf is a pioneer in digital amplification and one of the specialists in room correction. And the design is very nice. I guess next year a bit less Scandinavian modesty is in order!

Apart from its large range of high-end products, Naim (www.naimaudio.com) displayed the second generation of its Mu-so Premium Wireless Speaker. This stand-alone wireless music system is packed with features, which make it a useful (lifestyle?) product. With reinforced power (450 W), the second-generation Mu-so is suitable as the music center piece in a living room, offering direct connection possibilities for almost everything from Airplay2, Bluetooth, and Chromecast to Internet radio, Spotify, and Tidal. A very complete product.

The new DSP processor is now 10 times more powerful than its predecessor. A nice feature is room compensation. Also, now with the HDMI ARC connection we can use the second-generation Mu-so as a soundbar placed against the wall. Due to the close relation with Focal the sound is excellent. Somehow this product does remind us of a tabletop radio from the 1980s. No comparison of course regarding quality and features, but the use might not be so different. The price tag, around 1500 Euros (USD \$1,599) shows this is a very serious product (see **Photo 10**).

Turntables

Pro-Ject (www.project-audio.com/en) always has a large booth in the main exhibit halls, filled with its exceptionally large product assortment. Most people know Pro-Ject as the largest turntable manufacturer in the world—and the number of turntable models and ranges keeps growing. The company's latest product is the X1, part of the X-series, in which Pro-Ject continues to develop top-class turntables.

The new X1 improves upon the original Pro-Ject 1 turntable, launched in 1991, the brand's first and very successful high-end, low budget turntable, now selling for \$700 USD without a cartridge.

During the last few years, Pro-Ject also became known for a number of EISA award-winning products (e.g., the Pre Box S2 Digital and the Stream Box S2 Ultra). New in Munich, was the CD Box RS2 T (see **Photo 11**). This CD player with a CD-Pro 8 drive claims to be one of the best CD players in the world. Remarkable is that this is a transport-only CD player

with S/PDIF, AES /EBU, and I²S + Masterclock via HDMI outputs. As we are used from Pro-Ject, this CD drive comes in a rather small format.

Music Streaming and Recording Opportunities

Another highlight for this year, music streaming service Qobuz supported the Dynaudio Unheard initiative. Dynaudio Unheard offers unknown artists a chance to make recordings in a portable studio (two full-sized containers with glass windows). These recording sessions, including professional support and production are completely free for the artists that sign up. The two containers were positioned on one of the outside courts of the MOC and, as both containers had glass windows, one could witness the recording sessions (see **Photo 12**). Unfortunately, the rain didn't help and the artists could record undisturbed by spectators... Qobuz (www.qobuz.com) will now offer access to the recorded projects on its streaming platform.

Car Audio

And with this year show floor completely booked, the car audio section was not so large this year. Still, in one the top atriums, visitors were pleasantly surprised to find a Bugatti Chiron with a sound system designed by the German manufacturer Thiel & Partner/Accuton (<https://accuton.com/en-home>).

Dirk Vaehsen, the technical director at Thiel & Partner, explained the challenges of designing sound systems for these super-cars: "In modern vehicles, the density of technical elements is extremely high. There is simply too little space. This results in an exciting technological task for us in terms of high-quality music reproduction. An imaginary stage needs to be created in the vehicle on which the performers rather than the loudspeakers are located." For the Bugatti Chiron, they installed nine extreme high tech drivers, all exclusively developed for the project (see **Photo 13**).

Headphones

There is good, better and simply the best. It does not happen often that you get a recommendation to listen to a pair of headphones with the remark that after that, you do not need to listen to the rest.

In this case it was the Warwick Aperio system (www.warwickacoustics.com). I have to admit that after that experience it was indeed difficult to listen to other products and to focus on product qualities and not what was missing compared to... Yes, this is an electrostatic headphone, made with Warwick's Balanced Drive High Precision Electrostatic Laminate (BD-HPEL), and combined with a headphone amplifier



Photo 13: If you can afford a Bugatti Chiron, would you settle for the standard audio system? Some custom designed speakers from Accuton for the Bugatti Chiron.



Photo 14: Zoltán Bay with its formidable BayZ loudspeakers at the hifideluxe show.



Photo 15: Tube sound at its best, the Western Electric 91-E. A new proprietary Class A2 parallel feed current source topology (patent pending), combined with toroidal output transformers, and microprocessor controlled automatic bias.



Photo 16: The Thorens reel-to-reel tape machine. An analog expansion to the famous brand.



Photo 17: The floating Pre Audio turntable with a built-in air compressor for the floating tangential tone arm.

with all options and connections including an ultra-high-performance DAC and network streamer. The Aperio has been designed as a reference headphone system. Soundwise? Let's put it this way. I played some recordings I thought I knew... and only now I can say I know them....

In a corner of the High End, we met Claus Zapletal from Zapletal Akustik, Berlin (<http://zapletal.net>). It becomes rather common to have ear protection or in-ear headphones custom-fitted to our ears.

If you ever have the opportunity to have a test pair fitted to your ears, I would highly recommend it. The Zapletal Akustik in-ear headphones come as two-way or even three-way systems. You can send your ear prints (which should only to be done by a professional) to Berlin for a pair of these highly exclusive in-ear phones. In such a large event, fortunately there is still room for high-quality small scale initiatives.

BayZ Audio

Two years ago, we were invited to a special listening session to experience the new BayZ Audio Radial Speaker (BRS), designed by Zoltán Bay. Stunningly good it was. Last year, BayZ Audio (www.bayz-audio.eu) surprised everyone with the Courante speaker, using its exclusive BRS tweeter technology combined in a unique design with SB Acoustics Satori woofers, designed in collaboration with Frank Nielsen of Danesian Audio, and András Voloscsuk of Composite Project Kft.

This year, we were back at the Hifideluxe show to listen to the new flagship Counterpoint loudspeaker system, basically an expanded, larger version with larger drivers. Again we were impressed with this very special setup. The resulting omnidirectional sound and detail is brilliant. A set of Counterpoint loudspeakers has an undeniable physical presence in the listening room, but more important is its musicality (see **Photo 14**).

Tube Amplifiers

At any edition of the High End show, you can find many tube amplifiers. Apart from the "if we incorporated tubes in the product, it becomes high-end" category of products, there were a few manufacturers that genuinely did their best to present a very good tube amplifier. The first to mention is Western Electric (www.westernelectric.com). Now with a new factory that started to be constructed a couple of years ago, they are seriously back in production with the famous 300B. They are also investigating some tube designs, which were never before released. The presentation of the 91E amplifier fits perfectly with their ambitions, and the demo was great fun (see **Photo 15**).

Reel-to-Reel Recorders

The surprises continued. The well-known turntable manufacturer Thorens (www.thorens.com/en) surprised High End visitors with a new reel-to-reel tape recorder. This tape machine was developed together with Düsseldorf-based Manufaktur Ballfinger, and expands Thorens' analog product portfolio with another traditional component. It's a half-track, quarter-inch design with three motors. It handles reels up to 10.5" with speeds of 19 or 38 cm/s. CCIR equalization for most European recordings and NAB for the Americas and Asia can be selected. An edit function for single-handed operation is integrated. The base for this machine is the newly developed very compact tape drive from Ballfinger. With only 50 mm in height it gives a freedom of design that has not been seen before. Head and capstan motor are placed far from each other to generate a very high signal-to-noise ratio (see **Photo 16**).

Floating Arms

And sometimes you see a product idea that is not new but is fun to watch. Tangential arm turntables have existed for quite some time. The idea to use air to let the arm float has been done before.

However, new was the approach of Polish company Pre Audio (www.pre-audio.com/en) to ingrate the air compressor into the turntable itself. A rather bold idea as normally you would expect this compressor to affect the rest of the structure by generating vibrations or sound. Pre Audio apparently solved the problem and presented a beautiful turntable that not only looked good but also played music on a high-end level (see **Photo 17**).

Wrap-Up

Several years ago, the High End show allowed us to clearly see the transformation from analog to digital audio, step by step. Analog audio is still here, but digital is evolving and reaching new quality levels. This show, I believe, was the first step to accelerate that transformation. What Purifi Audio presented in Munich could transform Class-D amplification. No, they do not glow in the dark, they don't need large heatsinks. But unless you like to see an amplifier glowing in the dark, or particularly like the coziness and warmth of tubes, you might find yourself one day having an amplifier that is mathematically correct... Time for a Bavarian beer. There is much to think about. 



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Meet PureAudioProject

Trio15 Heil AMT Speakers

A meeting with Ze'ev Schlik, founder of PureAudioProject, leads to an opportunity for our author to learn more about his company and to experiment with the Trio15 Heil AMT speakers, which feature the ESS Heil AMT 1.

By
Oliver A. Masciarotte
(United States)

Trio15 Heil AMT

PureAudioProject, Ltd.
11 Hakabaim St.
Ramat Gan
Israel 5225511
pureaudioproject.com
Cost: US \$4,790

Ze'ev Schlik has worn several hats over the course of his career, all centered around audio. For a while, he was a senior executive at Comverse Technology—a company known for its AudioDisk recording products for telecoms and for pioneering technology, enabling music delivery over cellular networks. Later, Schlik ran an Israeli record label, Zuta Music. Some of its releases are still available. For six years, he also managed NMC Music, a major contemporary classical label in Israel and a licensee of SonyBMG and EMI. Nowadays, he heads up PureAudioProject, a direct sales company taking a modular, semi-DIY approach

to open-baffle loudspeakers. PureAudioProject is headquartered in Israel, with a US office in Iowa City, IA, manned by Thomas Sulentic.

I initially came across PureAudioProject at a hi-fi show, and a subsequent enjoyable 2016 presentation by Sulentic for my local Audio Society of Minnesota convinced me of their chops. I first bumped into Schlik at the 2018 AXPONA, who told me that, without *audioXpress*, his company probably wouldn't exist (see sidebar).

The Product

So it was that one day three large black road cases appeared in my garage. One held six newly painted baffles, another four boxes of woofers and crossovers, and a third with ESS's 6" Air Motion Transformers (AMT) and assorted hardware. My example, as supplied, was decked out with black frames and white baffles (see **Photo 1**).

Available materials and finishes include black or white frames, four shades of laminated oak, two flavors of triple layer bamboo, eco-friendly Valchromat composite in a range of 10 factory colors, plus birch in gloss white and black. The oak option has the most strength, with a custom bidirectional laminate. A vertical end grain jacket surrounds a horizontal grain core. Valchromat—I had to look this one up—is a rigid amalgam of dyed wood fiber and low VOC resin, with higher mechanical strength than



Photo 1: The large version of ESS' Heil AMT, mounted on its baffle

an equivalent thickness of MDF, greater resistance to bending forces, and better moisture immunity. PureAudioProject manufactures in Europe and the US to supply local markets.

The way I received the product is as an “Audition at Home” customer would. The OB-A15Neo woofers are manufactured to PureAudioProject’s specifications by Eminence. Jerry McNutt, Product Design Manager at Eminence, said on the PureAudioProject site that they are a higher performance and lower distortion 15” model specifically optimized for use in open-baffle applications (see **Photo 2**). “They share the same cone and surround as the Alpha15, but are (otherwise) different. With the neodymium version, we went with (a) cast basket, stronger neodymium magnets, 2.5” voice coil motors to gain more motor strength, increase linearity, increase power handling, lower power compression, and to be able to add shorting rings to lower distortion and lower the Le (the voice coil inductance in milliHenries, usually at 1 kHz). To further lower distortion and cut down on basket ringing, (we used) our rigid cast aluminum frame, (and an) open basket for minimum turbulence...”

The Build

One afternoon, I spread out all the components, looked up the tutorials on my iPad, and started the build (see **Photo 3**). A couple of hours later, I had a set of speakers! w00t! The trickiest part was attaching the woofers to their baffles. Thank goodness the baffles were predrilled, including eight pilot holes for each woofer’s screws.

After that, it was a matter of burning them in for about 200 hours. At first, I found the treble to be slightly aggressive and shelved it down a bit (-1.6 dB). Since I’ve run them in, the high-frequency response has tamed itself and I no longer need any high-frequency suppression. When I mentioned this to Schlik, he echoed my observations, mentioning that they advise customers to reserve sufficient time for proper break-in.

Listening Tests

For my initial listening, I pressed my trusty (40 W in 8 Ω) Class A Lindell AMPX into service. Not long after, Linear Tube Audio sent me a ZOTL Ultralinear for review, and the folks at SPEC CORP sent me a pair of their RPA-W3EX (100 W into 4 Ω) Class-D amplifiers for evaluation. Although the ZOTL Ultralinear was an excellent match with the controlled impedance of Spatial Audio’s M3 Triode Master OB speakers that I also had in-house, the ZOTL did not enjoy the Trio15s, producing an unappetizingly frequency response. Kent Peterson’s measurements



Photo 2: An Eminence direct radiator in situ



Photo 3: Supplied attachment hardware makes baffle mounting a breeze. Note the wide elastomer grommets and black composite knurled nuts.

(see his companion article) revealed a range of impedance, from about 4 Ω to a bit over 5 Ω with sharp transitions, which may have accounted for the uneven sounding result. My Lindell AMPX, on the other hand, had no problem driving the Trio15s, and the RPA-W3EX brought their ample power and tight control of the low end to bear for excellent effect.

Speaking of impedance, the PureAudioProject OEM custom crossovers come from Mundorf, which uses



Photo 4: The Trio15 custom Mundorf crossover



Figure 1: My optional EQ setting as seen in Amarra Luxe

its premium MCap EVO series capacitors, MResist SUPREME low-inductance bifilar resistors along with the laminated, oriented grain Feron core MCoil BS series, and big, BL series air core inductors. The Trio15 crossover (see **Photo 4**) comes with gold-plated jumpers that let the user tamp down, by 2 dB, the highs, mids, and low end. After experimenting with crossover settings, I ran the speaker flat, which resulted in a perfect overall energy balance.

Over time, I settled on a speaker position 3.5' from the back wall, 8' from the rear wall, and about 6' apart. Via e-mail, Schlik mentioned that the crossover

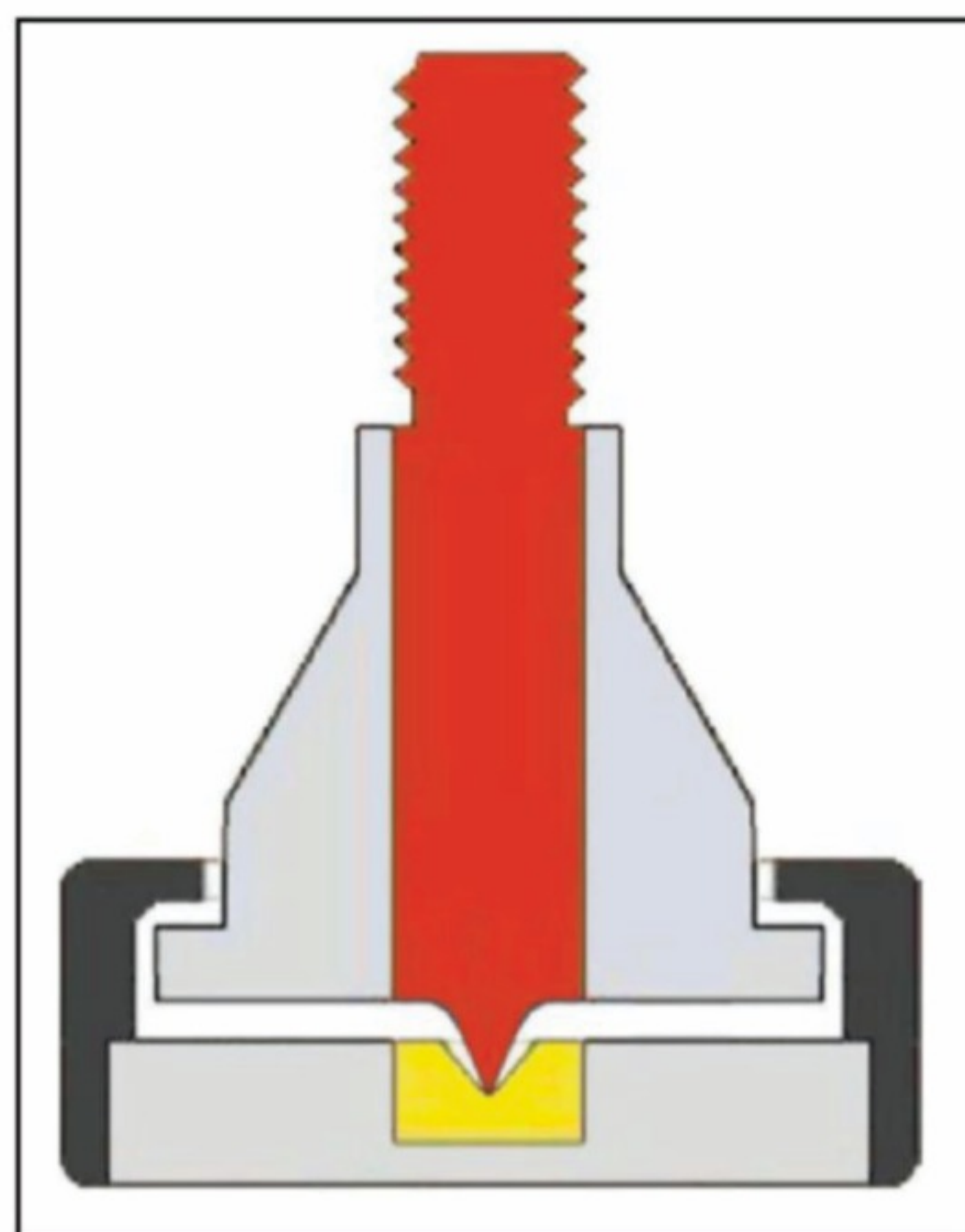


Figure 2: Cutaway of the standard model Soundcare SuperSpike

is minimalist, with an extremely short audio path. He enumerated; "...one coil for the low woofer (first order), one coil and one resistor for the mid woofer (also first order) with a light notch filter at higher frequencies to shave the rise the Eminence have, and a simple second-order high-pass filter for the Heil. That's it!" He added that he could have smoothed the response a bit but other issues would have cropped up. "One of the reasons you hear what you hear is exactly because of this transparency, and the goal is 'what you hear and how you hear and feel' and not to have the most beautiful spec on paper." His guiding principle is to have "reasonably good measured (response) and great sounding speakers!"

My esteemed and iconoclastic colleague, Siegfried Linkwitz, died during the course of this review, and I thought it best to revisit some of his voluminous technical essays during my review. Since he was an outstanding exponent of open-baffle speakers, I went digging through his musings and happened upon his recommendation for subtracting a small amount of energy in the 1-to-3-kHz region to improve spatialization.

Sure enough, on most symphonic recordings a 2.4 dB dip (first-order bell with a Q of 1 at 2 kHz) yielded a subtle but noticeable improvement in imaging and spaciousness. The phantom center seemed to cohere better and subtly sit comfortably where it belonged. With synthetic recordings, pop and close mic'd jazz, the midrange dip didn't seem to detract so I left it in for much of my listening. Since I wasn't using a subwoofer during this period, I did add some low-frequency shelving from Amarra Luxe's equalization to lend some weight to the bottom octave (see **Figure 1**).

Note that, though I utilize EQ, the Trio15 Heils do just fine on their own, factory flat. Some folks think that open-baffle speakers cannot possibly deliver low end due to diffraction and cancellation, but I found the Trio15s to deliver plenty of bass. I'm going to steal a line from fellow reviewer Hartmut Quaschik when I say the Trio15 Heils exhibit "...electrostatic resolution with real life dynamics." Granted, if you want bottom octave slam and startle factor, then open baffle speakers may not be your first choice. That said, I found their bass response to be natural, coupling as they do organically with a room. With no EQ, warble tones didn't diminish in strength until 44 Hz and were audible much lower than that.

The factory feet are spiffy Soundcare SuperSpike Standards. They're a nicely chromed M8 metal spike captured in a plastic composite cup, with a layer of felt on their underside (see **Figure 2**).

I couldn't help wondering if IsoAcoustic feet would offer the same improvements I perceive from their

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Photo 5: The Trio15 Heil telegraphs both power and presence. Here, seen with the IsoAcoustic GAIA II isolators for floor-standing speakers, which provided a noticeable improvement.



ISO-L8R decouplers I use on my stand-mounters. Reaching out to Dave Morrison at IsoAcoustic resulted in two boxes of his GAIA II isolators for floor-standing speakers appearing on my stoop in short order. The GAIA II are weight-rated for the Trio15 Heils, and include an open-end wrench along with four sets of threaded adapters. One set are M8, so it was quick work to swap them in for the SuperSpikes. I started with one side only, and went back and forth in mono between the two choices of feet. It didn't take long to realize the GAIA II tightened up the attack of percussion and improved articulation of transients while reducing a slight tubbiness in the upper bass. In other words, way mo' better bottom! Though not essential, GAIA IIs are well worth the cost given the refinement they provide.

Once the Trio15 Heils had settled in, I too sat down with both my exaSound e22 Mk. II DAC and Mytek's MQA-capable Brooklyn DACs as conversion. On 1939 Ensembles' *New Cinema* album (TIDAL 44.1), the synth and vibes-driven instrumental has a traditional trap drum kit to move it along. With

the Trio15, the drum kit says it was distant mic'd, appropriately small so as not to overwhelm the other contributors. Contrast that to Our Girl's "In My Head" (Qobuz 44.1), a pop confection with a big reverb-soaked sound and a "giant" drum kit, the sprawling gargantuan kind that close mic'ing tends to create. The Trio15 had no trouble conveying the differences in character between these two very different production techniques.

The Trio15's AMT has an admirable way of revealing the limitations of a recording without tearing your head off with "detail" or "sizzle." Hozier's "Nina Cried Power" (TIDAL 44.1k) has what sounds like the papery signature distortion of a very multitracked Pro Tool session. Crunchy is good in a breakfast cereal but not in a neo-soul album, and the Trio15s telegraphed that unfortunate engineering choice without euphonious smoothing or concealment.

On the first part of Gustav Mahler's "Symphony No. 3" in D Minor; Kräftig. Entschieden off of Bernard Haitink: *Portrait* (BR Klassik/Naxos 44.1k ALAC), the tympani play a foundational subterranean role. The Trio15 Heils, despite many people's tendency to expect anemic low end, offered highly convincing and appropriate percussive force without the artificiality that many sealed or reflex boxes tend toward. As my friend and fellow audio geek Don Meger mentioned during a listening session, open baffles simply couple to a room better than boxes at low frequencies. His overall opinion, "Mightily impressed!"

BJ The Chicago Kid's "Turnin' Me Up" off his album, *In My Mind* (TIDAL 44.1), has a very jazzy feel for a funky pop tune. After the breakdown as the end of the song nears, some tinkly percussion is exposed as other instruments fall away. That metallic time keeping actually imaged just outside the left speaker. I heard the same outside-the-speaker effect with Gregory Porter's "Nature Boy" (Qobuz 48k) from his *One Night Only* album.

During one of my listening sessions, I became entranced with Liz Wright's gorgeous cover of Nick Drake's "River Man" (Qobuz 44.1). Delivered with refined vocal immediacy overlaid by a supple blanket of Hammond, trumpet and guitar, the track is in sharp contrast to Drake's original. On "Five Leaves Left," a string section intrudes on Drake's centered guitar and voice. Wright's smoky version is more in keeping with Kurt Elling's jazzy approach on Lee Ritenour's album *Rhythm Sessions*. The Trio15 Heils offered unbiased timbral insight into each production.

The Verdict

One aspect to consider with speakers is Spousal Approval Factor (SAF). Though they are relatively imposing in my listening space, they have received

About the Author

O. A. Masciarotte has spent more 30 years immersed in the tech space, working on facilitation, optimization, marketing, and product development for clients worldwide. As an author and speaker, he enjoys informing folks about technological best practices. More information is available at seneschal.net and othermunday.com.

a high SAF rating from my wife Kari, both for their very shallow footprint and exceptional performance (see **Photo 5**). Kari finds them good looking, gratifying in their presentation, and instructive to listen to given her reoccurring utterances of, “I’ve never heard THAT before!” Having had to move these units several times over to Warkwyn for measurements, I also appreciate their modular nature, making for easy, single-handed break down and transport.

As Zora Neale Hurston once said, “Ships at a distance have every man’s wish on board.” At \$4,790 a pair including shipping, the Trio15 Heil isn’t one of those “If you have to ask the price...” luxuries.

When one thinks of the rare and exotic in audiophile terms, myriad choices of unobtainium spring to mind. Yet, as a limited production, modular open baffle speaker, the Trio15 Heil is both rare and exotic. Their performance is extraordinary, especially when weighted against their cost, with an unrestricted presentation, wide and smooth response, and rugged, techy good looks. Their honest timbre, excellent speed at mid and high frequencies, and overall sense of envelopment is pure listening pleasure. In terms of fidelity—the truth in conveying what’s in a recording, they smoke many loudspeakers costing several times

as much. Heck, I like their overall performance more than some costing 10 times more. Highly Recommended!

In the sidebar “Trio15 Heil Speaker Measurement and Listening Tests,” Kent Peterson conducts a more rigorous set of tests on PureAudioProject’s Trio15 Heil AMT speakers. 

Ancillary Equipment

Amplification:

SPEC CORP RPA-W3EX (\$11,500 MSRP) and H-VC5 controller (\$1100 MSRP)
SPEC Corp. | www.spec-corp.co.jp

Lindell AMPX (\$1,600)

Lindell Audio | www.lindellaudio.se

Cabling: VUE Digital VU-3 (USB), Soundstring GEN II Beta 2-22S (XLR), AntiCable Level 3 (speaker), Soundstring GEN II Digimax-18 (power)

Conversion: exaSound e22 Mk. II

Mytek Digital Brooklyn | <https://mytekdigital.com/hifi/products/brooklyn>

Isolation: IsoAcoustics GAIA II (\$300)

IsoAcoustics | www.isoacoustics.com

Source: Amarra Luxe 4 (\$99)

Sonic Studio, LLC | www.sonicstudio.com/amarra

Meet Ze’ev Schlik

One day, Ze’ev Schlik and I talked on Skype about his background, and his initial push from audioXpress that slotted him into a consumer audio track. What follows is a lightly edited version of his discussion with me.

I spent a few good years in the music business and high tech, and was exposed to home audio around 2013. When I first experimented with open baffles, it fascinated me. The results were extremely musical. The simplicity of it, the ability to control various aspects easily was there, (but) I was not sure at the beginning whether it would develop into a business or not. What I think triggered my look into making it a business was its popularity with DIYers. If you searched “open baffle” at the time, you got thousands of projects, while in home audio, it was not existing. There was one or two companies, but the vast majority were not aware of this option. This gap was the trigger to think about it professionally. There’s a lot of experience and know-how, years of experience in DIY and Pro Audio as well. In pro audio, this concept is well known and well used. On the other hand, in home audio, there was almost nothing. There was Jamo, (along with Emerald Physics and late lamented Dahlquist—OM) but nothing that caught on. I was on the borderline, we had a prototype that was quite close to what we have today but not as mature, and me and my partner were debating whether to go professional, to try a show. We contacted the Munich (High End) Show, and the show management suggested we apply to the “newcomers” program. Every year, they invite a few companies as newcomers, they

give you the booth space, you present your stuff and they host you. There are no expenses other than travel.

So we took a prototype and went to Munich, and it was a bit premature... this is an understatement! (Laughs) You cannot play (your gear) there, but people can see and feel and touch. It was modular, you could touch the components, you could mount them, dismount them. When the show was over, we started getting comments in the press, which were very positive and, boom! In, I think, the August issue 2013, *audioXpress* covered the Munich Show and we were in the feature article. Now you mentioned (myself), who was still not sure there is a business case or enough interest to turn it into a business. Then (we) got the coverage in *audioXpress*, and another three or four very positive mentions by the press. Basically, I think *audioXpress* was the kickoff; “O.K., we are going into it professionally, we are going to take that path.”

I asked Ze’ev about his first hi-fi experiences, and he mentioned a Fender Rhodes he received early on in life, which captivated him. It was only much later that he realized its amplified cabinet was an open-baffle design.



Ze’ev Schlik heads up PureAudioProject, a direct sales company that takes a modular, semi-DIY approach to open-baffle loudspeakers.



Trio15 Heil Speakers Measurement and Listening Tests

By
Kent Peterson

PureAudioProject's Trio15 Heil, featuring the ESS Heil AMT 1, was measured at Warkwyn's facility using the Klippel Near-Field Scanning system (NFS). The NFS delivers a 360° "balloon" of data, allowing for an examination of the radiation pattern, off-axis frequency response, and any frequency-important information that might help when determining where to place this impressive dipole in your listening environment (see **Photo 1**).

The Measurements

For the measurements of the Trio15, we used 3.5 VRMS. A calibrated ACO Pacific free-field microphone with the 4048 pre-amp and the 7052E capsule was used and all on-axis data is referenced at 3 m and centered on the Heil AMT high-frequency transducer.

Measurement points around the speaker totaled 3034 and were processed with a resolution of 18 points per octave and from 20 Hz to 20 kHz. The length of the stimulus was 0.40 seconds with an average of 4.

Initial measurements of the Trio15 Heil had the crossover jumper switches in their default or flat mode, as delivered to Warkwyn. A second measurement was made with the jumpers for the mid and high frequency positioned in their "cut" position.

Our first analysis is an examination of the sensitivity through 15°, 30°, and 60°. Before examining the frequency response curves, we remind the reader that the device under test (DUT) is a dipole speaker configuration and with that come some pretty jagged response curves as a result of the cabinet-less design along with the acoustic shortcut around the cabinet that allows complex interference and summation across many frequencies. The frequency response curves measured here are anechoic and do not take into account any room influence, which make good dipoles a pleasure to listen to. With that in mind, **Figure 1** shows the on-axis, 15°, 30°, and 60° frequency curves.

Examining the frequency curves and on-axis, a pronounced boost is apparent between 200 Hz and 800 Hz, a narrow 10 dB notch at 1 kHz and after recovery, a nicely extended high frequency. The radiation pattern holds together nicely to approximately 1 kHz but falls off sharply at 1.2 kHz to 2 kHz indicating a "hole" in response at 30°. This recovers at 60° and then attenuates as one would expect at wider angles. An "unwrapped" 360° pressure/f contour map shown in **Figure 2** provides a complete view of the horizontal radiation of the speaker through its measured frequency response.

The horizontal contour mapping affirms the frequency-response curves on-and off-axis measurements but also reveals the beam width of the Heil AMT, which came with the system. Anechoically, the Trio15 Heil exhibits the classic figure of 8 pattern of a dipole, with plenty of bass fore and aft, and horizontal radiation at 1 kHz at about 100°, narrowing to 20° and then recovering at 10 kHz.

Photo 1: PureAudioProject's Trio15, featuring the ESS Heil AMT 1, was measured at Warkwyn's facility using the Klippel Near-Field Scanning system (NFS).



Figure 3 shows the unwrapped vertical contour map. Upon examining the vertical contour mapping, the collapse of the high-frequency radiation pattern from 80° at 1 kHz to about 20° is apparent, while the low frequency is consistent with the horizontal contour mapping.

There are holes between 800 Hz and 1 kHz in the horizontal

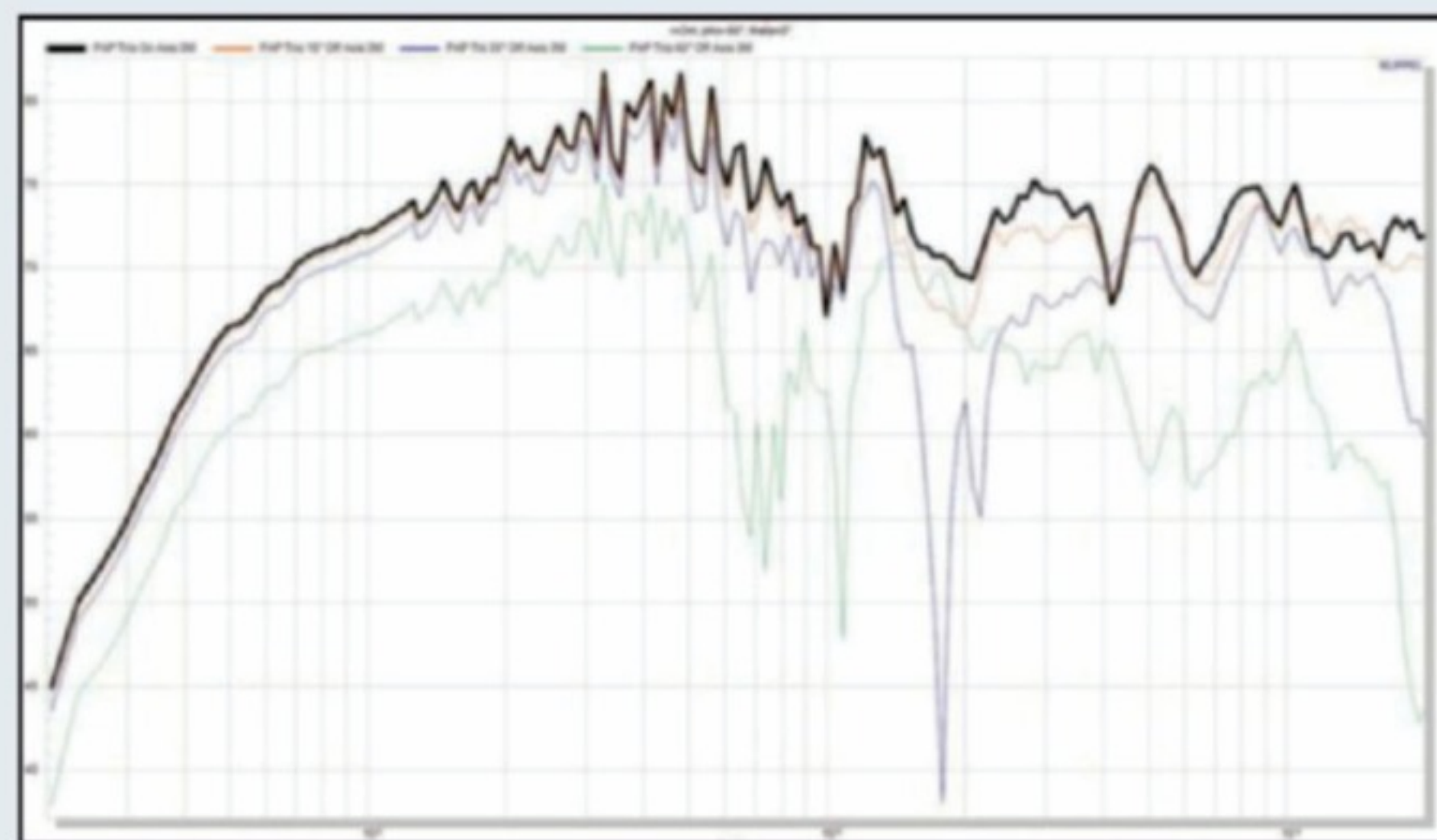


Figure 1: Horizontal sensitivity on-axis, 15°, 30° and 60° (no smoothing)

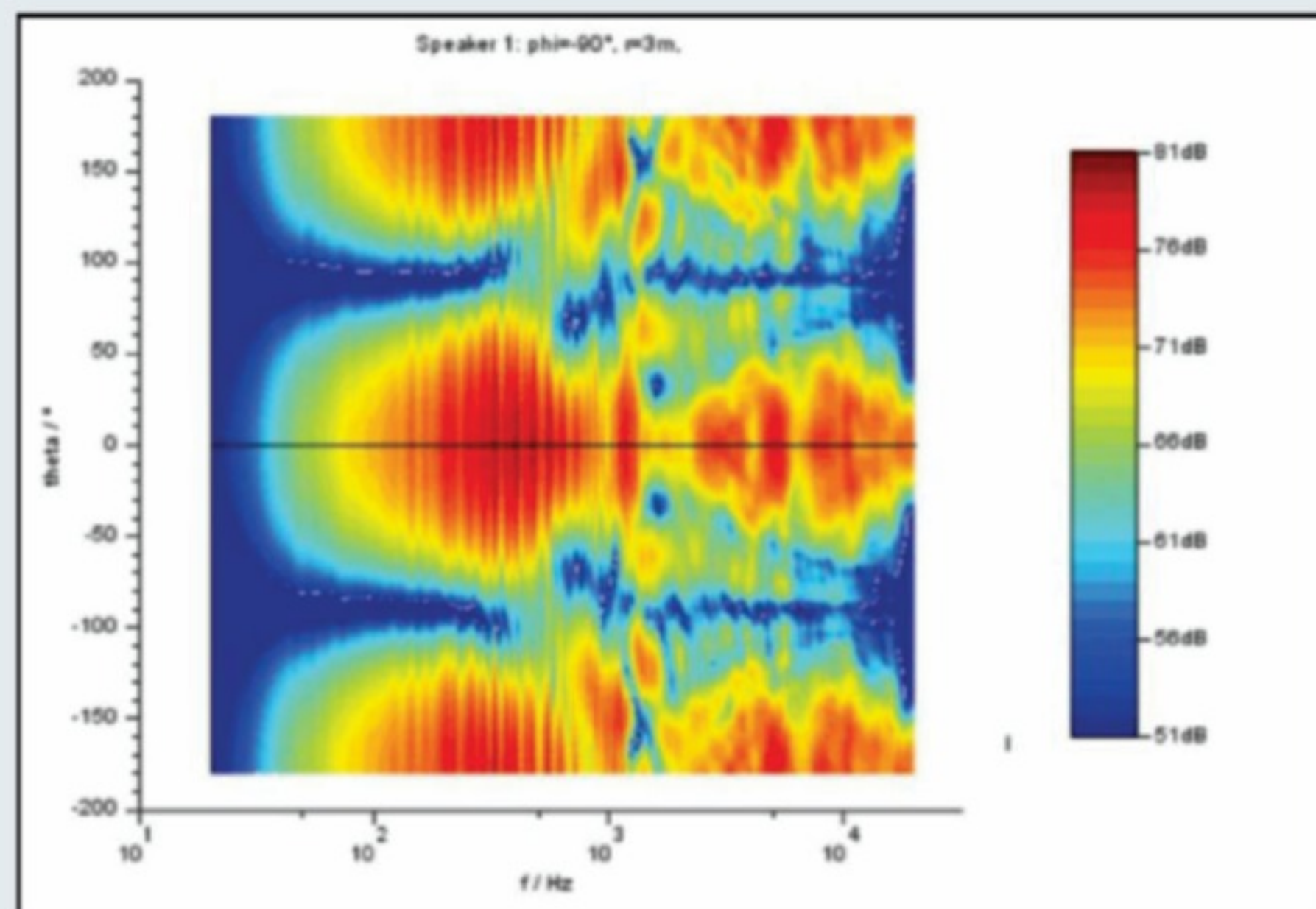


Figure 2: Unwrapped horizontal contour map



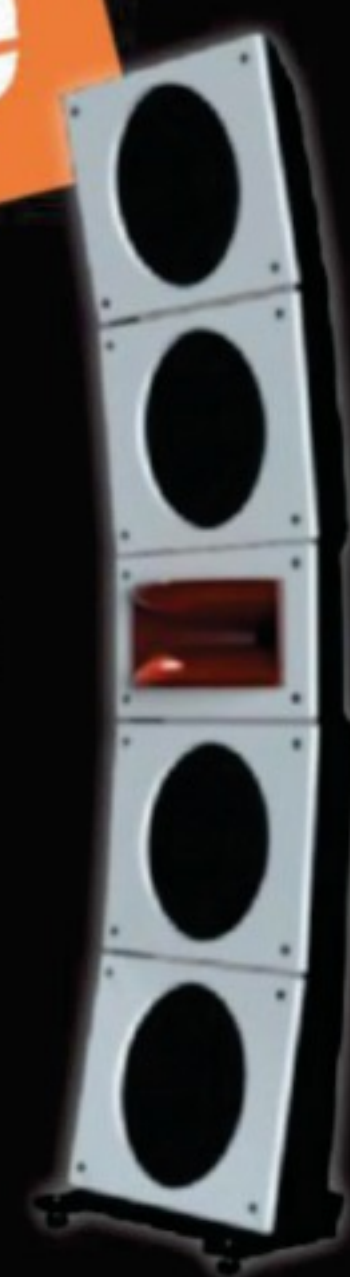
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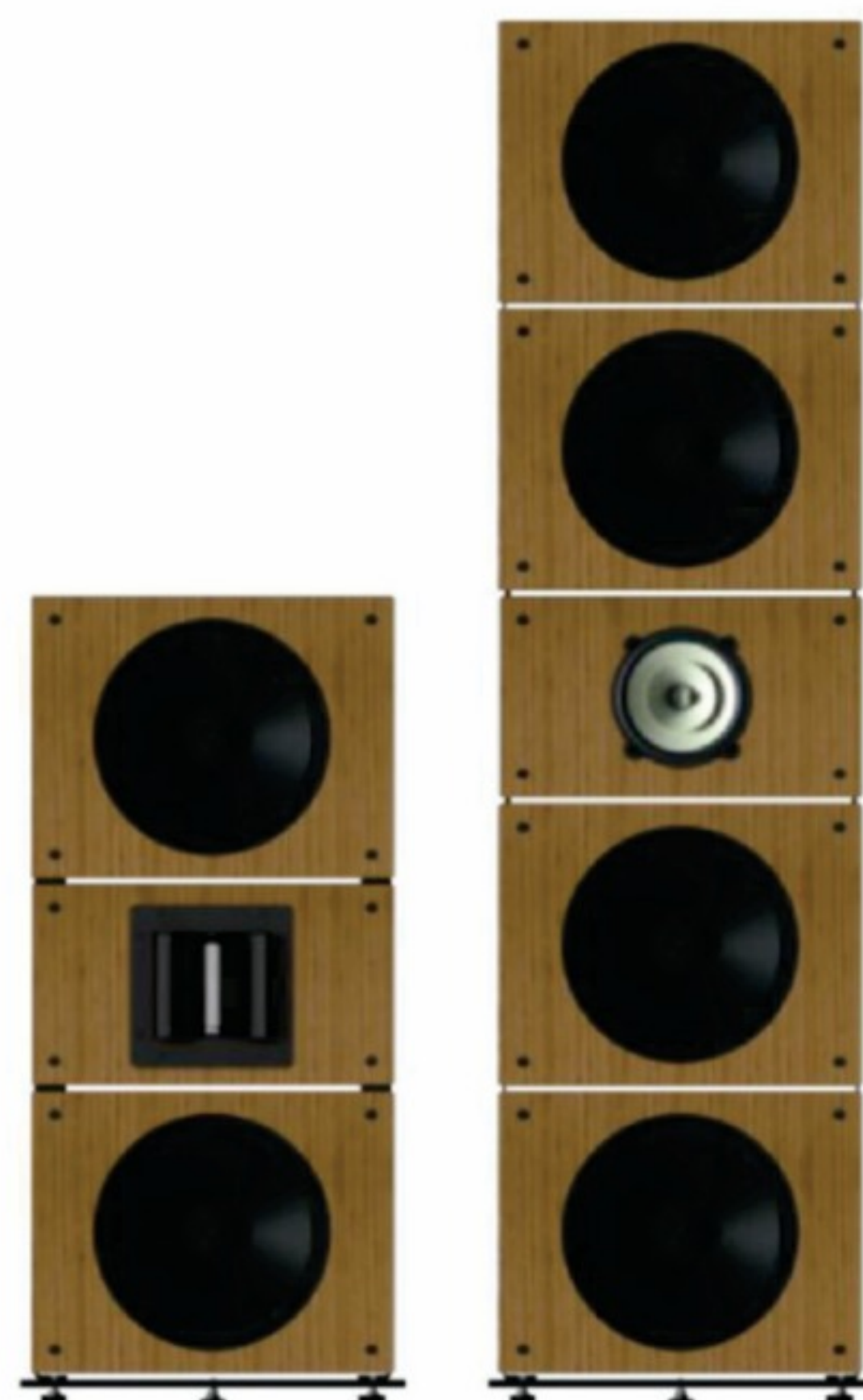


PERFORMANCE

We base all models on the sonic virtues of the finest audio components and drivers available today.

SIMPLICITY

PureAudioProject speakers are assembled by you. All models are engineered for easy assembly requiring only a hex key and a screwdriver.



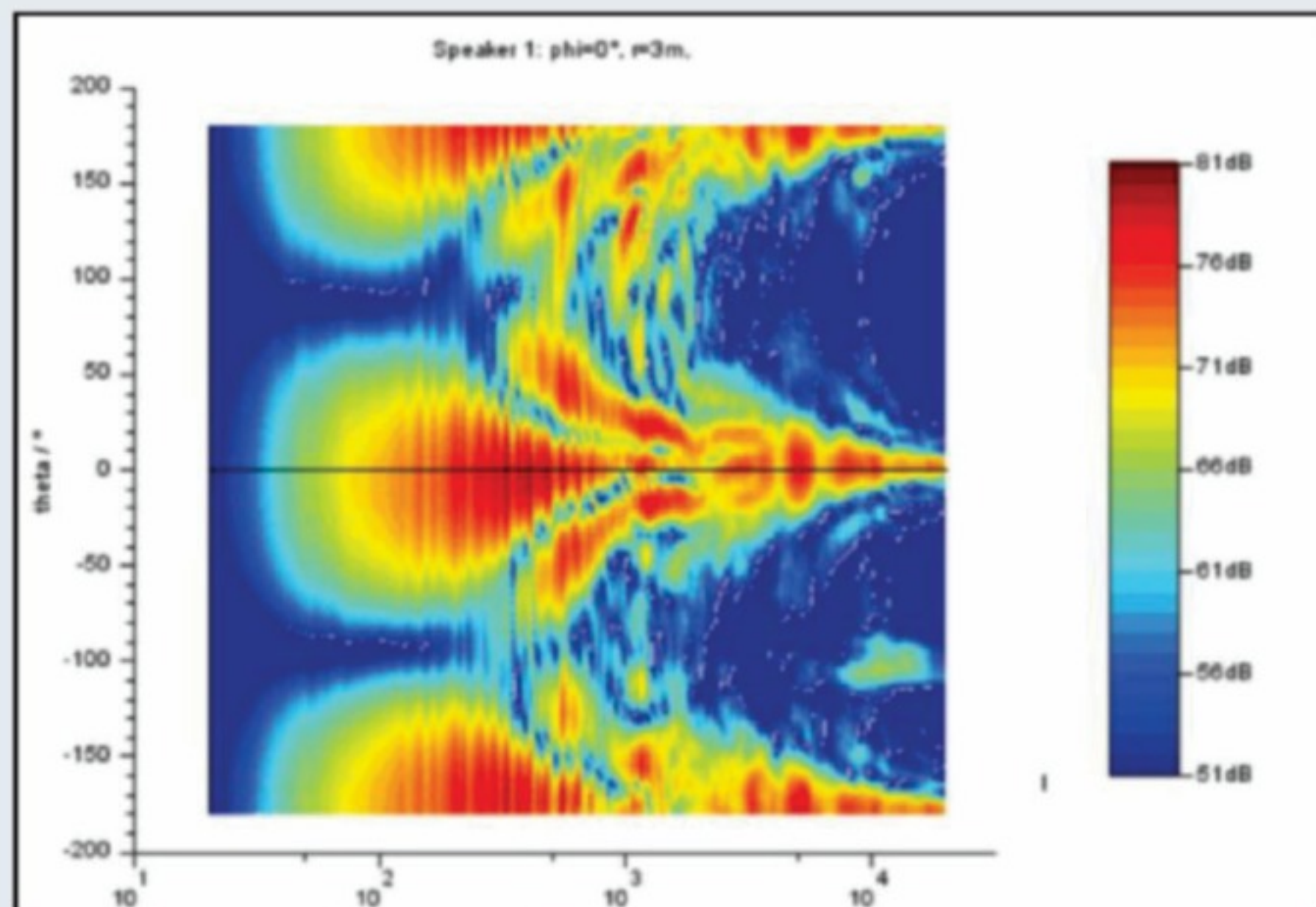


Figure 3: Unwrapped vertical contour balloon

mapping, that are recovered somewhat 20° to 80° off axis in the vertical mapping, owing to proximity of the upper and lower 15" transducers. Overall, the listening window is quite narrow in the vertical and much wider in the horizontal.

A second measurement was made with the low-frequency and mid-frequency jumpers moved into the "cut" position*. **Figure 4** shows a comparative frequency response curve. No big surprises here as, with the jumpers positioned in the alternative position, there is an approximate 2 dB to 3dB cut in the mid and lower frequency ranges.

Finally, the impedance was measured with the jumpers in the default configuration shown in **Figure 5**.

The free-air resonance of the 15" transducers is at about 41 Hz, with nominal system impedance of 4 Ω. There looks to be a high-pass filter at about 45 Hz with a high-frequency crossover for the AMT at approximately 2.5 kHz. Overall the impedance and phase appear to be in good order with no anomalies to be concerned about.

Listening

I'll admit up front that apart from working with dipole speakers in a laboratory setting my experience with dipoles is limited. Have I heard many of them? Of course—at trade shows and show rooms. But let's face it, those are not good places to listen objectively and actually formulate an opinion that you can have confidence in hours

later. However during those times I have found most dipoles lacking in definition, low-end punch, and with a very tiny listening window.

On a cold, dark night, I was invited to Oliver Masciarotte's home where we spent a considerable amount of time listening and orbiting the speakers in his listening environment while we sipped herbal-flavored concoctions from a reservoir stored within "The Cabinet."

Respecting each other's tastes, we cordially traded our favorite and trusted listening songs back and forth. Time and cobwebs do not allow a good collection of my cohort's songs and artists, but we have similar tastes. As a starter I wanted to hear some music I had been recording for an upcoming release by Blake Miller and the Old Fashioned Aces—down to earth, honest to goodness Cajun from a true Cajun. This is music that is not intended to be awash in reverb but is simple and straight forward with high articulation, presence, and with a relatively small stage. My first impression was no—this does not sound like the high intelligibility mid-band that I was used to from studio monitors. But it was not unpleasant and yes, I know, this is obvious. But I wanted to get a sense of how different these speakers are in place of clinical monitors and mix positions on music with which I knew well.

Next, I chose something I knew would have a greater sound stage, with greater depth—Diana Krall's "The Look of Love." With a more expansive sound stage and luxurious production, I started getting it. Properly positioned between the Trio15s and with some supportive reflections from the wall behind the Trios, the sound stage opened to a glorious extent. There was still a bit of sibilance and articulation missing but the enveloping sound field washed away those concerns. Diana was singing to me and it sounded lovely.

Opting for something less languid, I moved to music from the Brother's Landreth and from the album *Let it Lie*, a little bit more raucous but also very well produced and open. Again, I was nicely enveloped in the sound stage and I had the elevated feeling of being right in front of the band, very nice. During a saunter to "The Cabinet," I came back and walked the room and listened from various angles. It was at this point I realized that I had lost the articulation I was getting used to. As I pulled back from the speakers and while still standing, it recovered somewhat but it wasn't until I sat back in my original listening position that it all came back to life. The vertical radiation pattern of the Heil AMT is tight and I found it best to have my head right on plane with the Heils—that's the spot.

The rub on dipoles is the lack of low-end punch and definition. Putting the Trio15s to the test I dialed up my old favorite Thomas Dolby

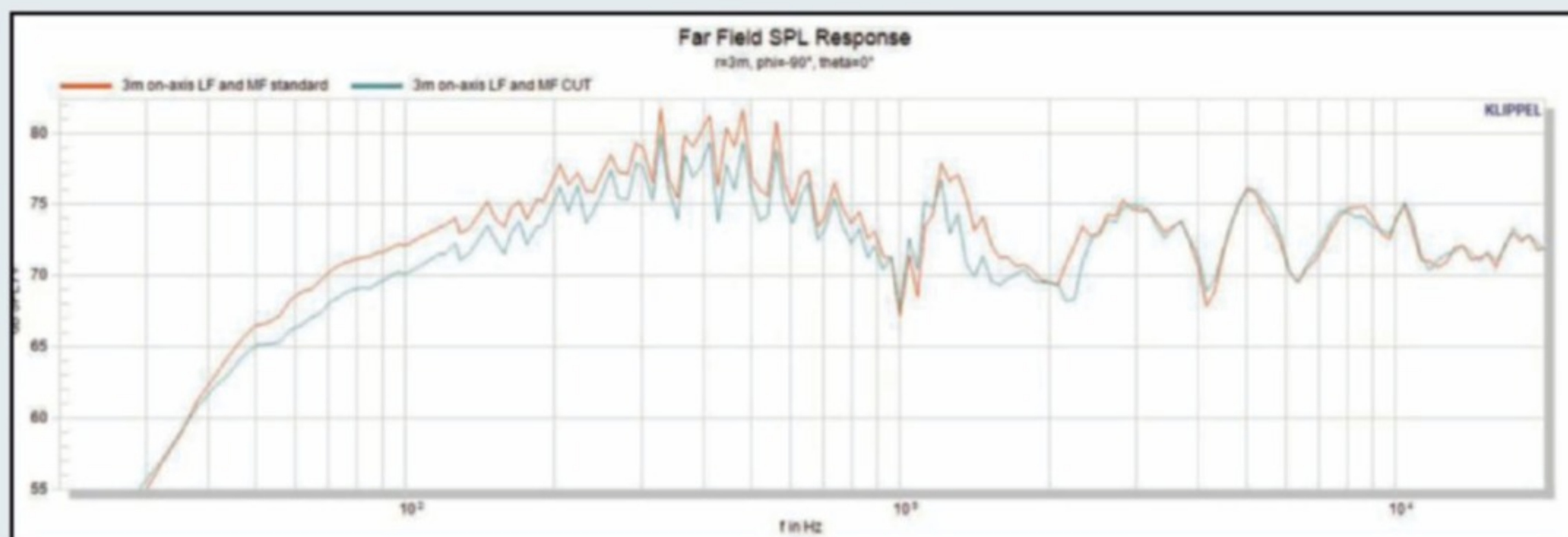


Figure 4: Frequency response with jumpers set to cut low/mid frequency

standards. No, not “She Blinded Me with Science”—that’s for Dolby amateurs. But rather “Pulp Culture” and “May the Cube Be with You,” recorded featuring Mothership Commander George Clinton (you didn’t know that did you?). No lack of bass here. With the 15s from the Trios providing good punch, and with my chest resonating, I was in my happy place. At this point and because it was timely, we switched the crossover jumpers to their cut position. This took a little bit of doing with some needle nose pliers which, unfortunately, took my acoustic memory right out of the picture. After repositioning and listening to punchy bass tracks, I couldn’t discern a huge difference so we opted to move back to the original jumper positions, and all was well.

Leaving that night, I realized I was quite enamored of these speakers. Some critical listening dispelled some of the reservations I had with dipoles, and I appreciate the austere and simple build quality, there is no need for satin oiled exotic woods in my world. I’d happily put these speakers in a larger room somewhere in my life along with my own “Cabinet.” 

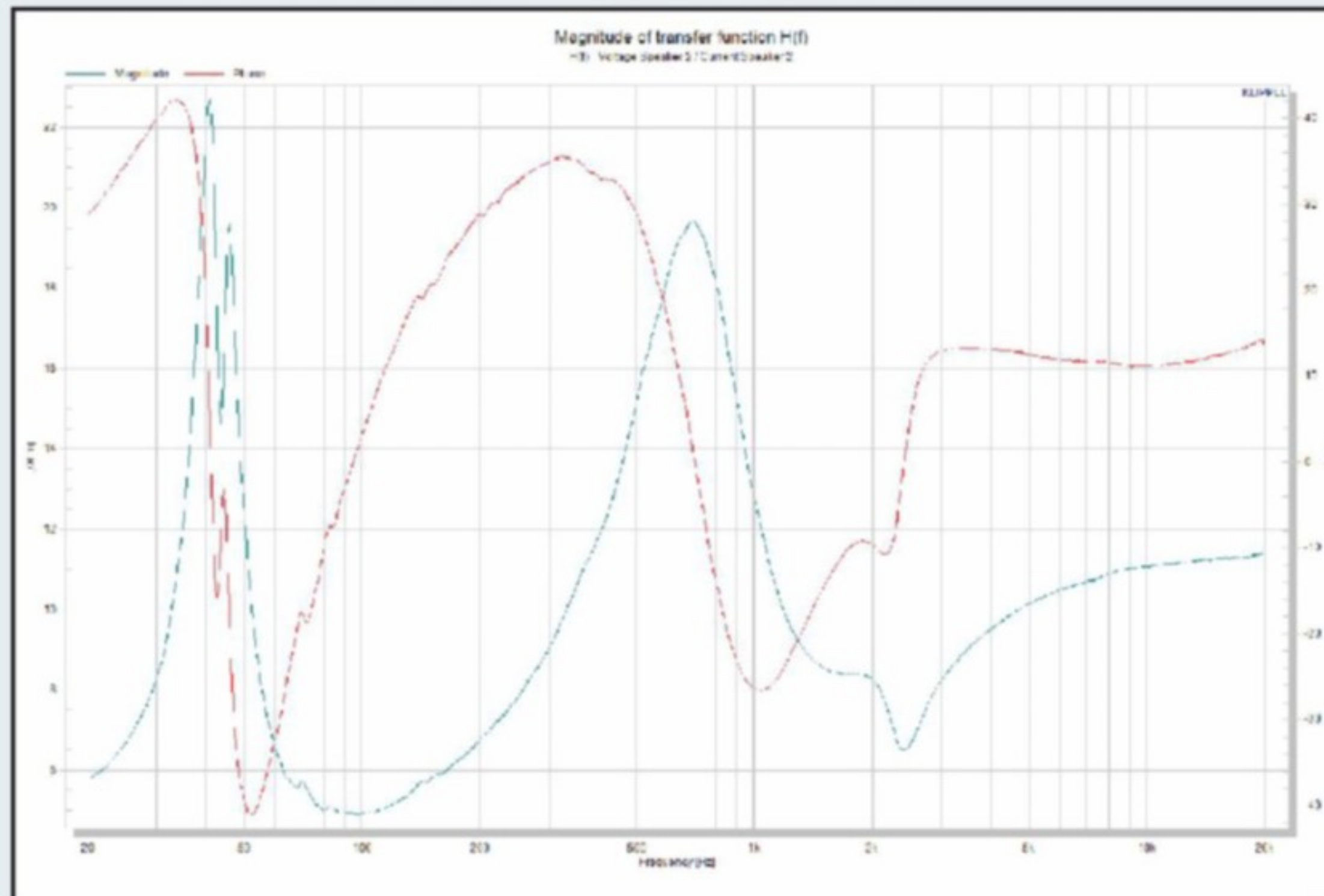
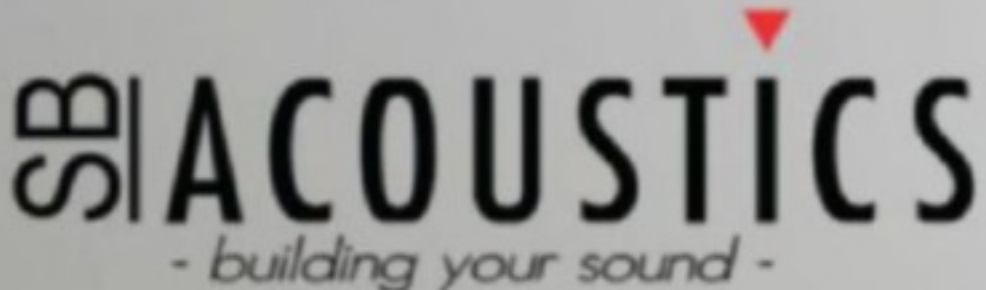


Figure 5: Impedance and phase for the Trio15 Heils



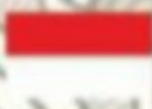
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- Soft low damping rubber surround for improved transient response
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The AXL Dipole Loudspeaker

George Ntanavaras tackles his next speaker project, which he dubbed the AXL loudspeaker. His latest creation is an open-baffle, four-way active loudspeaker that he has dedicated to one of his longtime role models, Siegfried Linkwitz.

By
George Ntanavaras
(Greece)



Photo 1: The AXL loudspeaker

The AXL loudspeaker is an open-baffle, four-way active loudspeaker consisting of five drivers: a 15" subwoofer, a 8" woofer, a 4" mid-range, and two 0.5" dome tweeters, one placed to the front and the other to the back side.

The loudspeaker is the result of my latest study after the completion of the Horizon loudspeaker, which had a dipole acoustic radiation up to about 2 kHz and was presented in *audioXpress* a few years back (see Resources). My main objective for this project was to design a loudspeaker that will have a dipole radiation for the full audio frequency range and the off-axis frequency response will be as similar as possible to the on-axis frequency response.

For the crossover of the AXL loudspeaker, I used a miniDSP 4x10 HD device. Its analog outputs drive eight power amplifiers, one for each driver. A front view of the completed loudspeaker is shown in **Photo 1**.

Design of the Low Frequencies Cabinet

To build an open-baffle loudspeaker that will cover the very low frequencies, you need to select a driver with parameters that include a large effective piston area and a large linear excursion with low distortion.

I chose the Ciare NDH 15-4 S for the subwoofer driver. This is a 15" (380 mm) unit with the enormous power handling of 1000 W and the capability to accept a maximum power of 2000 W. Its effective piston has an area of 830 cm² with 23 mm peak-to-peak excursion while its neodymium magnet offers a high sensitivity of 96 dB SPL/1 W/1 m.

The main design factor of an open-baffle cabinet for the reproduction of the low frequencies is the distance that separates the front radiation from the back, which should be as large as possible to isolate the subwoofer's back wave from the front and avoid cancellation. Several

different shapes can be used—having as a purpose to increase this distance in such a way that the total size of the cabinet will remain as compact as possible.

The Ciare NDH15-4S is a huge driver with an overall diameter of 388 mm (15.28") and a net weight of 8 kg. I used an N-frame cabinet with the driver baffle making a 45° angle with the sides of the cabinet as shown in **Figure 1**. This reduced the total front width of the cabinet to 375 mm (14.76"). The distance between the front and the back is estimated 400 mm (15.75"). Both the front and the back of the cabinet are open, just to have an idea of the needed equalization. **Figure 2** was created using the "SketchUp Make" program and shows the 3D-model of the cabinet without the driver installed. The final dimensions are 375 mm (14.76") × 480 mm (18.90") × 390 mm (15.35").

I used the Edge software to simulate the approximate far-field response of the subwoofer's open cabinet (see Figure 2). The piston area of the driver, according to the manufacturer, is 830 cm², which gives an effective diameter of 325 mm (12.79"). This value was entered to the software along with the baffle size 400 mm × 400 mm (15.75" × 15.75").

Figure 3 shows the simulation results. The peak in frequency response at $F_{pk} = 630$ Hz happens when the back radiation of the driver has shifted 180° due to the distance D and adds to the front radiation resulting to an increase of the total pressure. Below F_{pk} , the sound pressure falls with 6 dB/octave. This is due to the front-back cancellation of the sound. At the low frequencies, the distance D is small comparing to the length of the sound so it cannot provide any isolation between the positive and the negative sources. The far-field low-frequency roll-off has to be equalized with an electronic circuit that boosts the low frequencies in order to flatten the frequency response. If we consider 200 Hz as the upper frequency that the subwoofer will be useful, a boost of about 16 dB is needed between 30 Hz and 200 Hz.

When the low-frequency cabinet has the form of the N-frame, two cavities are formed in front and behind the driver (see **Photo 2** and **Photo 5**). Due to these cavities, a very broad resonance at around 230 Hz is created, as shown in **Figure 4**. This is the near-field frequency response measurement, taken very close to the openings of the subwoofer cabinet. This resonance is very broad because the openings of the cabinet are very large. The response rolls off at the low frequencies due to the low value of the driver's Q_{ts} (which is 0.25) and will also be equalized so a boost of another

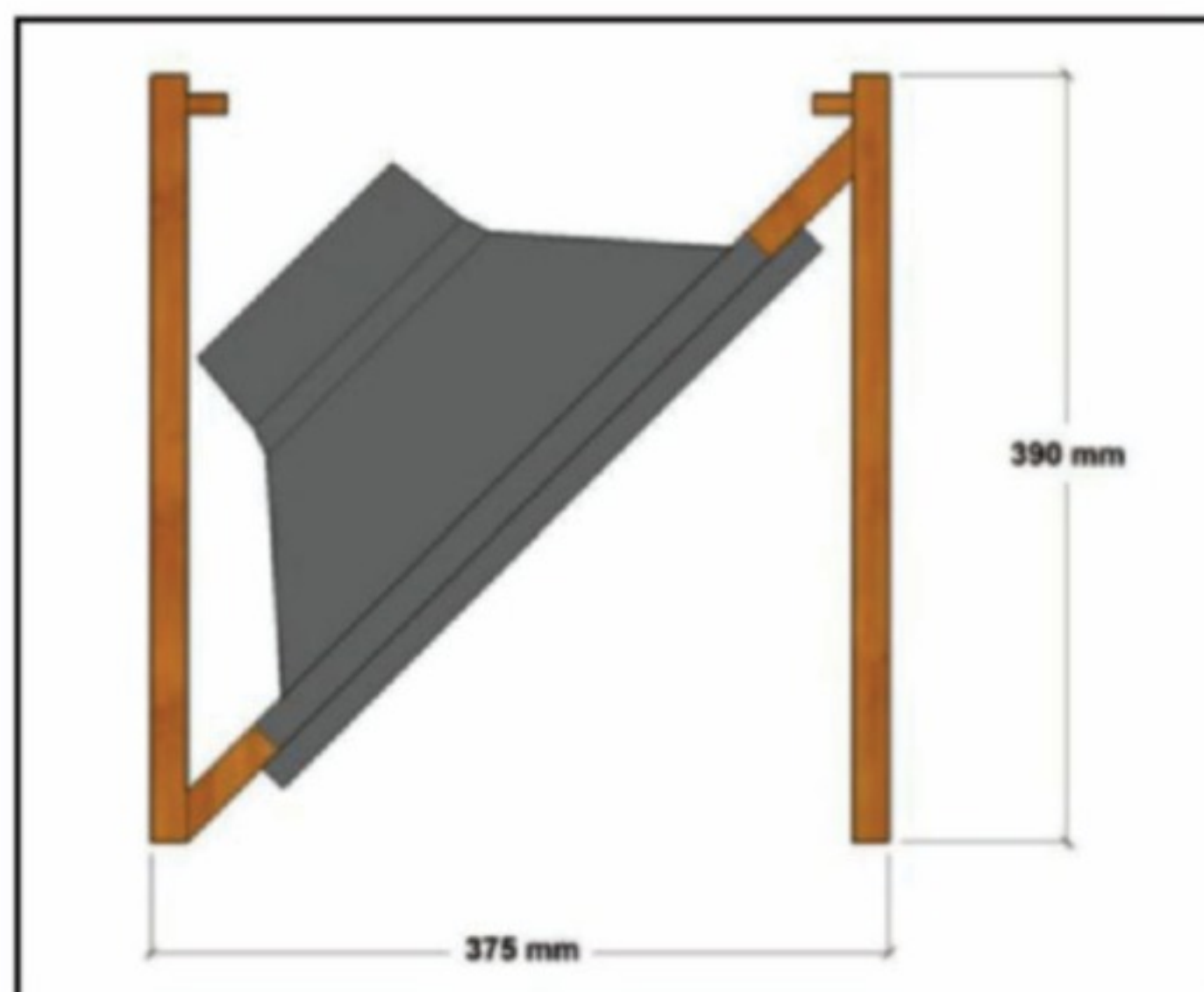


Figure 1: The subwoofer N-frame

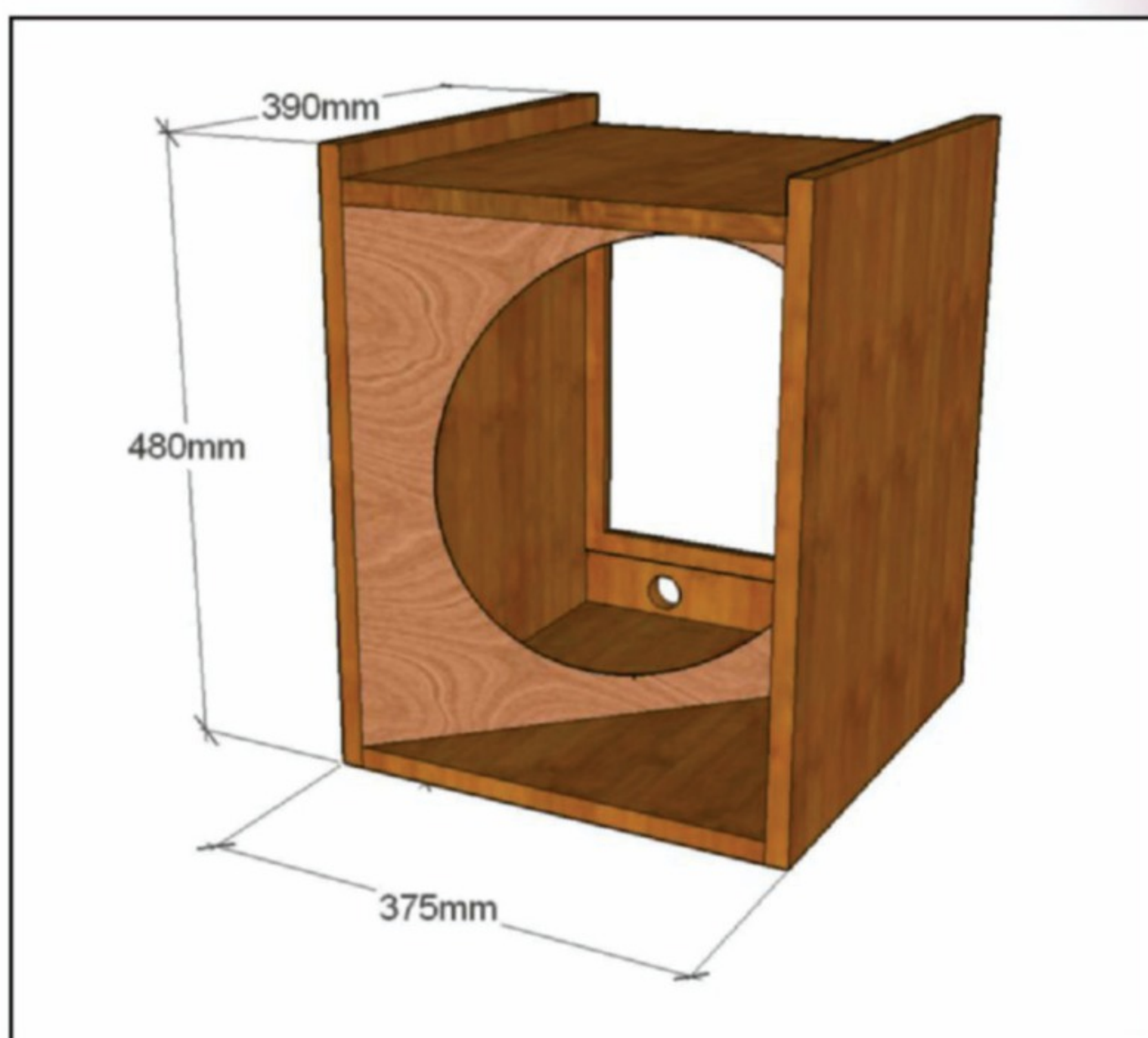


Figure 2: The subwoofer cabinet

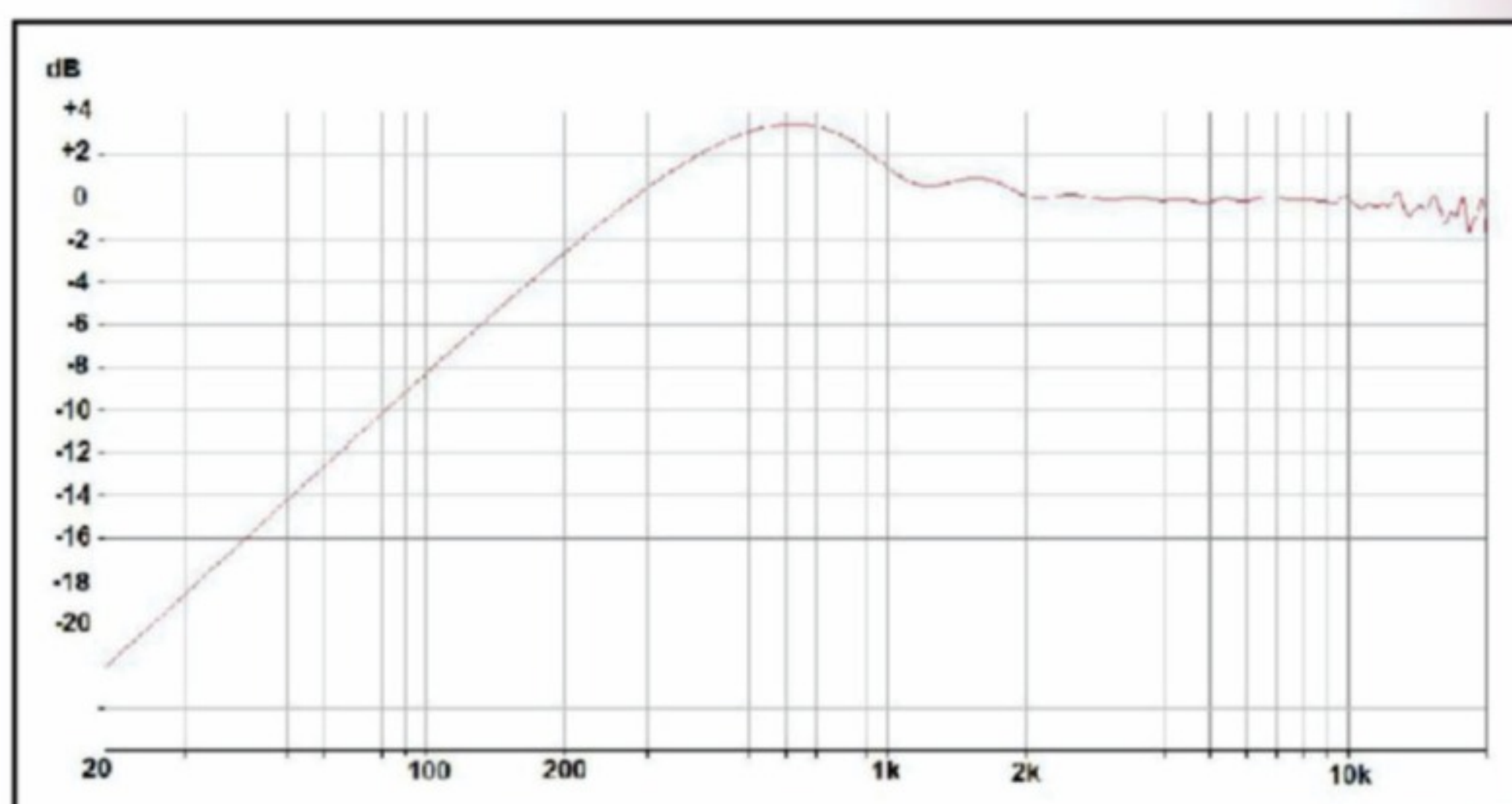


Figure 3: Simulated far-field response of the subwoofer open cabinet

16 dB is needed between 30 Hz and 200 Hz for a flat frequency response.

The Design of the Open Baffle for the Woofer, the Midrange, and the Tweeter

My previous loudspeaker, the Horizon, used a 6.5" mid-range and a 1" tweeter. Its baffle's shape was a little unusual as shown in **Photo 3a**. I eliminated the baffle around the tweeter as much as possible just to be able to support the tweeter,



Photo 2 : The pair of the AXL loudspeakers

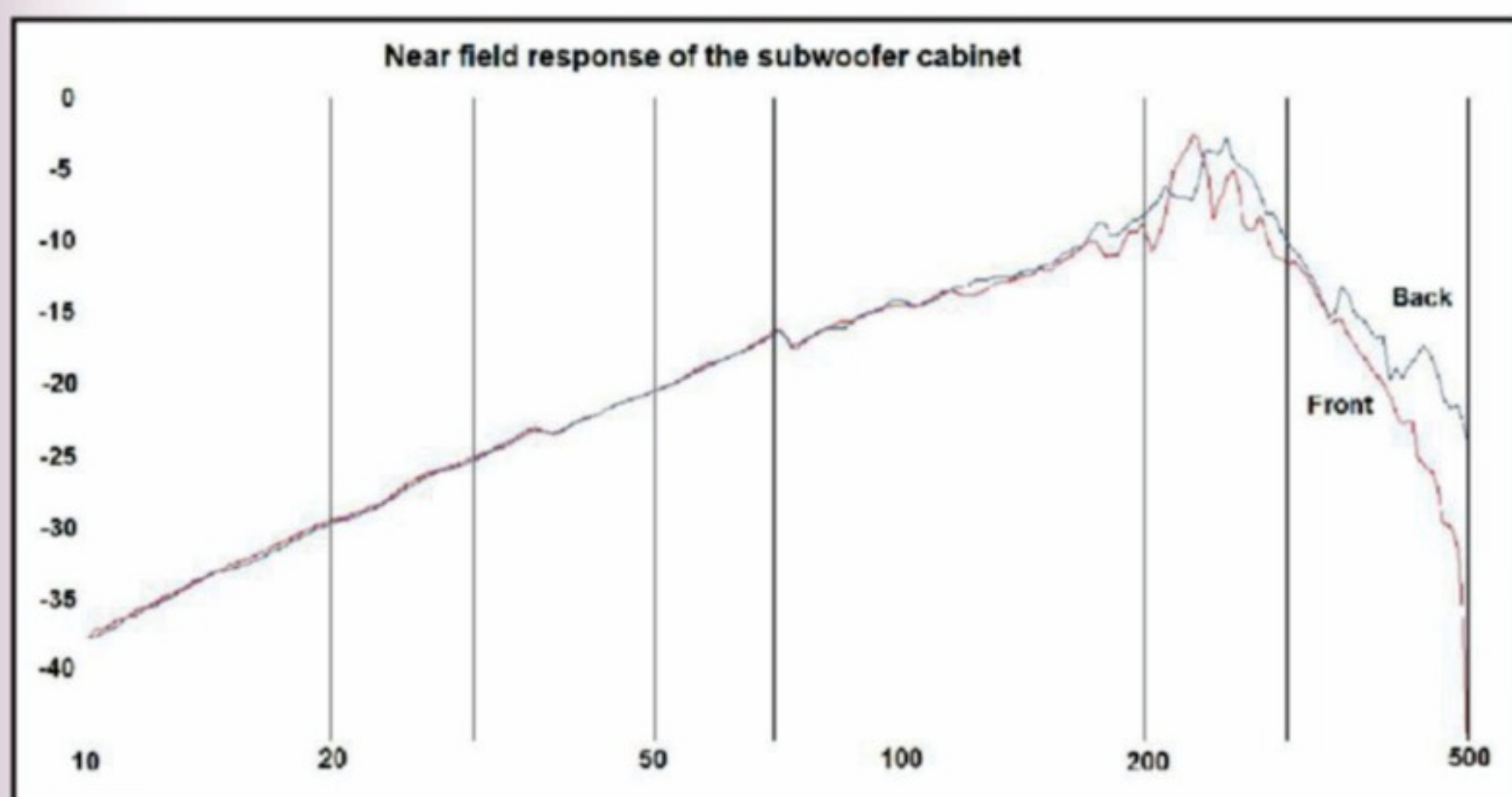


Figure 4: Near-field frequency response measurement of the subwoofer cabinet

because the polar response was more uniform—although there was a frequency range around 1 kHz to 2.5 kHz where the polar response of the midrange and the tweeter were broadening. I mentioned in the article that it would be possible to have a more uniform polar response if I used an additional driver with a very small baffle around it but I did not try it at that time.

When the Horizon was completed, I continued my tests trying to find a better shape that would have a more uniform dipole response for all the audio frequency range. **Photo 3** shows the evolution of the baffle design during my long-term experiments. The baffle shown in Photo 3b was my last attempt with a two-way system without much better results. I decided to continue with a three-way system and my first attempt is shown in Photo 3c. The results were much better.

At that time, Siegfried Linkwitz presented the LX521 loudspeaker and I decided to change my drivers with the lower and upper midrange drivers used in the LX521 since they were perfectly suited for the application. The result was the baffle shown in Photo 3d, which gave me much better measurements. At this point, I decided to add another tweeter radiating to the back side of the baffle and to eliminate the baffle around the tweeters as shown in Photo 3e. That change provided me with very uniform polar measurements, but there was a serious problem. The baffle was not very rigid or stable. After some thinking, more experiments, more measurements, and my wife's consultancy and final approval, I ended up with the baffle shown in Photo 3f. In this baffle, I used different and much smaller tweeters.

Photo 4 provides a closer look of the final baffle for the woofer, the midrange, and the tweeter. For the AXL loudspeaker I used the following drivers: For the upper woofer/lower midrange, I used the SEAS U22REX/P-SL H1659-08 driver. It is an 8" woofer with an injection-molded metal chassis. It has a Curv cone, made from woven polypropylene with excellent internal damping and a high-temperature voice coil wound on an aluminum voice coil former, which gives low distortion and high power handling capacity. The bullet-shaped phase plug reduces compression due to temperature variations in the voice coil and avoids resonance problems, which would occur in the volume between the dust cap and the pole piece and it increases the long-term power handling capacity.

For the mid frequencies, I chose the SEAS MU10RB-SL H1658-04. It is a 4" midrange with a Curv cone and a high-loss natural rubber surround. It has a large, open-weave fabric spider, which reflects very little acoustic energy to the cone.

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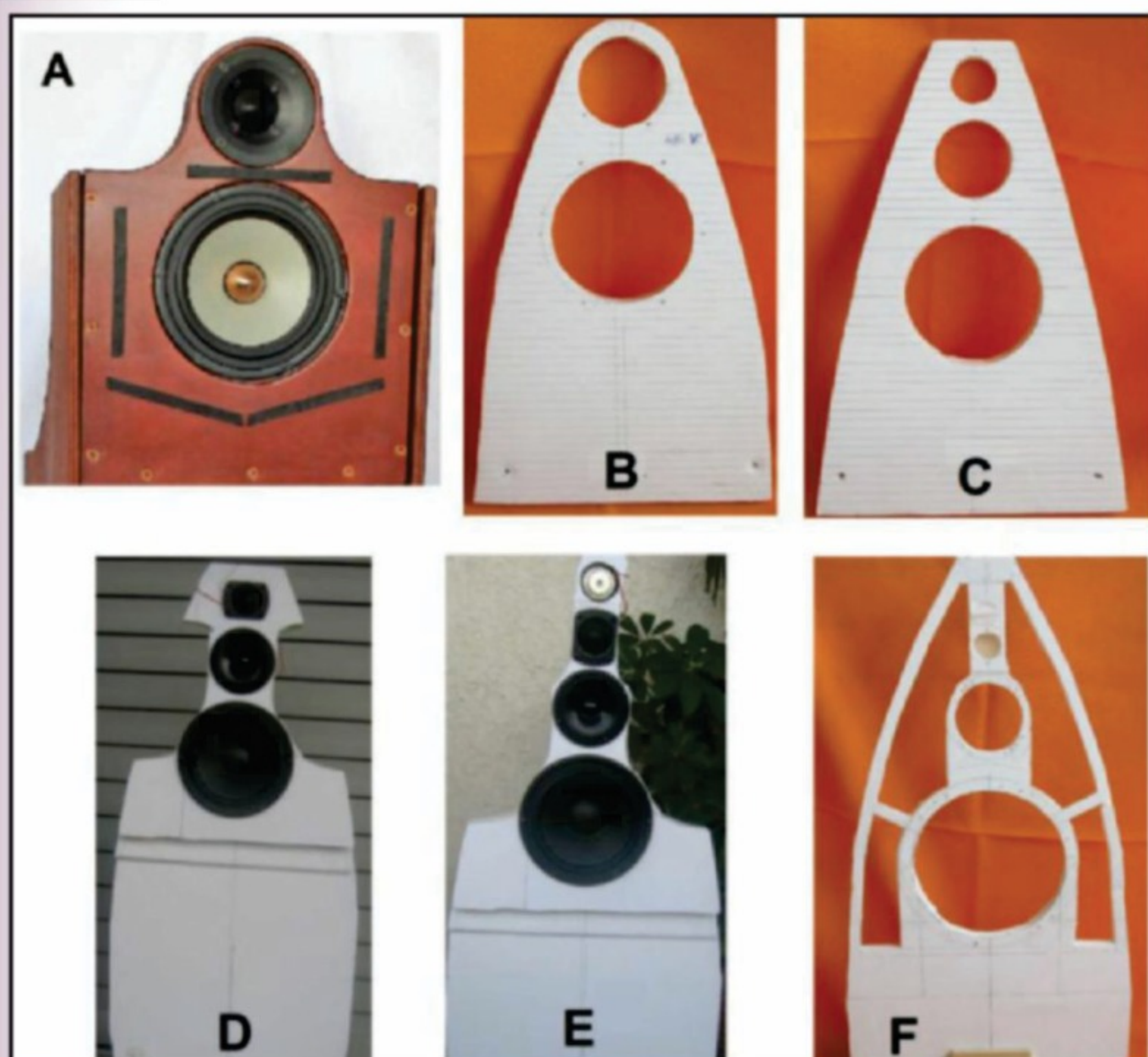


Photo 3: Evolution of the prototypes

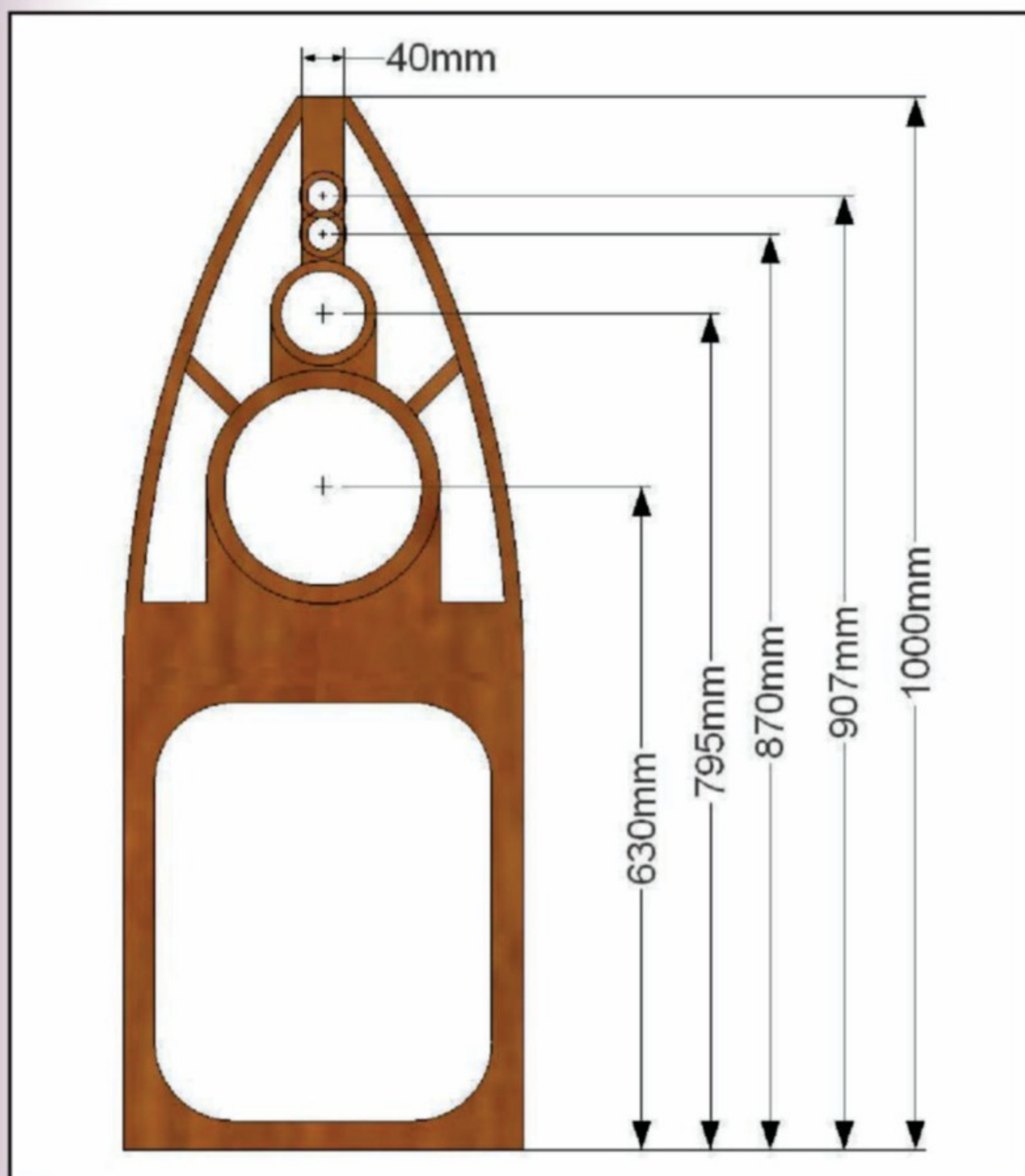


Figure 5: The dimensions of the AXL loudspeaker

For the high frequencies I chose the Wavecor TW013WA01 tweeter. This is a 0.5" very compact tweeter that is, according to the manufacturer, ideal either as a super tweeter in high-end hi-fi speakers or as tweeter in very small compact two-way systems. It incorporates an external ring neodymium magnet and offers, for its size, a very low resonance frequency at 1.3 kHz. I used two tweeters—one to the front and the other to the back side of the baffle. They are connected in series and simulate a dipole radiation.

The Loudspeaker's Construction

Figure 5 shows the dimensions of the loudspeaker's front baffle. The total height of the loudspeaker is 1 m (39.37") with the front tweeter standing 87 cm (34.25") above the floor.

The cabinet was constructed from 18 mm birch plywood. All the pieces were cut to the required dimensions at a local shop, making the assembly of the wood cabinet relatively straightforward. The subwoofer cabinet had some complexity since the sides of its internal baffle that supports the driver should be cut at 45°. I used my router to do this. The shape of the front baffle, shown in Figure 5, was formed by cutting a panel with dimensions 100 cm x 38 cm (39.37" x 14.96") with a jig saw. The holes for the drivers were opened with the router. When the front baffle was ready, it was glued to the subwoofer cabinet.



Photo 4: The baffle for the woofer, the midrange, and the tweeter

I carefully sanded all the cabinet's outside surfaces and I applied several layers of a wood-imitation varnish for a nice looking finish. I lightly sanded between every coat with smooth sand paper.

I surface-mounted all the drivers on the baffle, since there was not enough space for them to be flush mounted. The decorative grilles shown in Photo 1 were constructed from 15 mm plywood and an acoustically transparent cloth. The top grille of the loudspeaker is usually removed during critical listening.

I used an eight-contact Neutrik Speakon chassis-mounted connector to the back side of each loudspeaker for the connections as shown in **Photo 5**. This is a high-current connector with silver plating contacts and a very unique metal locking system, which makes contact only once fully locked.

An eight-pole female Neutrik Speakon cable mount connector is used to connect the multi-core cable that comes from the amplifiers with the speaker connector. The Speakon series comes from the professional audio world and is a very reliable and easy solution for the connection of these loudspeakers.



Photo 5: Back view of the AXL loudspeaker



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The Crossover's Design

The crossover of the AXL is implemented with a mini-DSP 4x10HD versatile multi-channel Digital Signal Processor (DSP). This device can function as a digital active crossover, a parametric equalizer for loudspeaker and room correction, a remote-

controlled volume, and a digital-to analog converter (DAC). For the setup, a plug-in running on a PC (or Mac) is needed. When the setup is completed, the PC is no longer needed and can be disconnected. The plug-in is operating at 96 kHz, while internally the algorithms are running with 56 bits resolution.

The first step for the design of the crossover is the measurement of each driver's frequency response. This is necessary for the selection of a suitable crossover frequency and the equalization of each driver for a flat response before and after the crossover frequency. The selection of the crossover frequencies is one of the most important decisions when designing a loudspeaker.

All the measurements should be taken with great accuracy. I don't have access to an anechoic room and I live in an apartment in a big city so outdoor measurements are not a possibility for me. I can only perform the measurements in my living room, which fortunately is large enough. Obviously, this implies some serious limitations mainly in the low midrange and bass frequencies so I used two different methods and setups to overcome this problem.

I used the first setup for measurements above 500 Hz. I placed the loudspeaker on a stand above the floor, away from the side walls with the microphone at 2 m from the speaker. The height of the microphone is 1.35 m (53.14") above the floor, which puts its axis in the middle of the distance between the floor and the ceiling. With this setup, it is possible to have a "reflection free" impulse response measurement for about 4 ms giving a resolution of only 250 Hz, which is not sufficient for assessing the loudspeaker's lower frequency performance.

For the lower frequency performance test, I used a second setup, similar to the ground plane measurement. I placed the loudspeaker on the floor and at least 1.5 m away from the side walls. Additionally, the loudspeaker is not perpendicular to the floor, instead it is inclined to the front so the distance of the drivers from the microphone is about the same as it would be in the listening position. The microphone is at a 2 m distance from the speaker and almost flush mounted with the floor.

For this, I built a special microphone consisting of a Panasonic WM-61A cartridge that is glued in a small piece of wood with the axis of the microphone forming an angle with the floor. This keeps the microphone's axis on the same axis with the loudspeaker, with no high-frequency loss. I take a lot of measurements at different points of the floor and I average all of them. This setup cannot eliminate the effects of the room, but I can get some useful results since I know the room's properties where the measurements are performed very well.

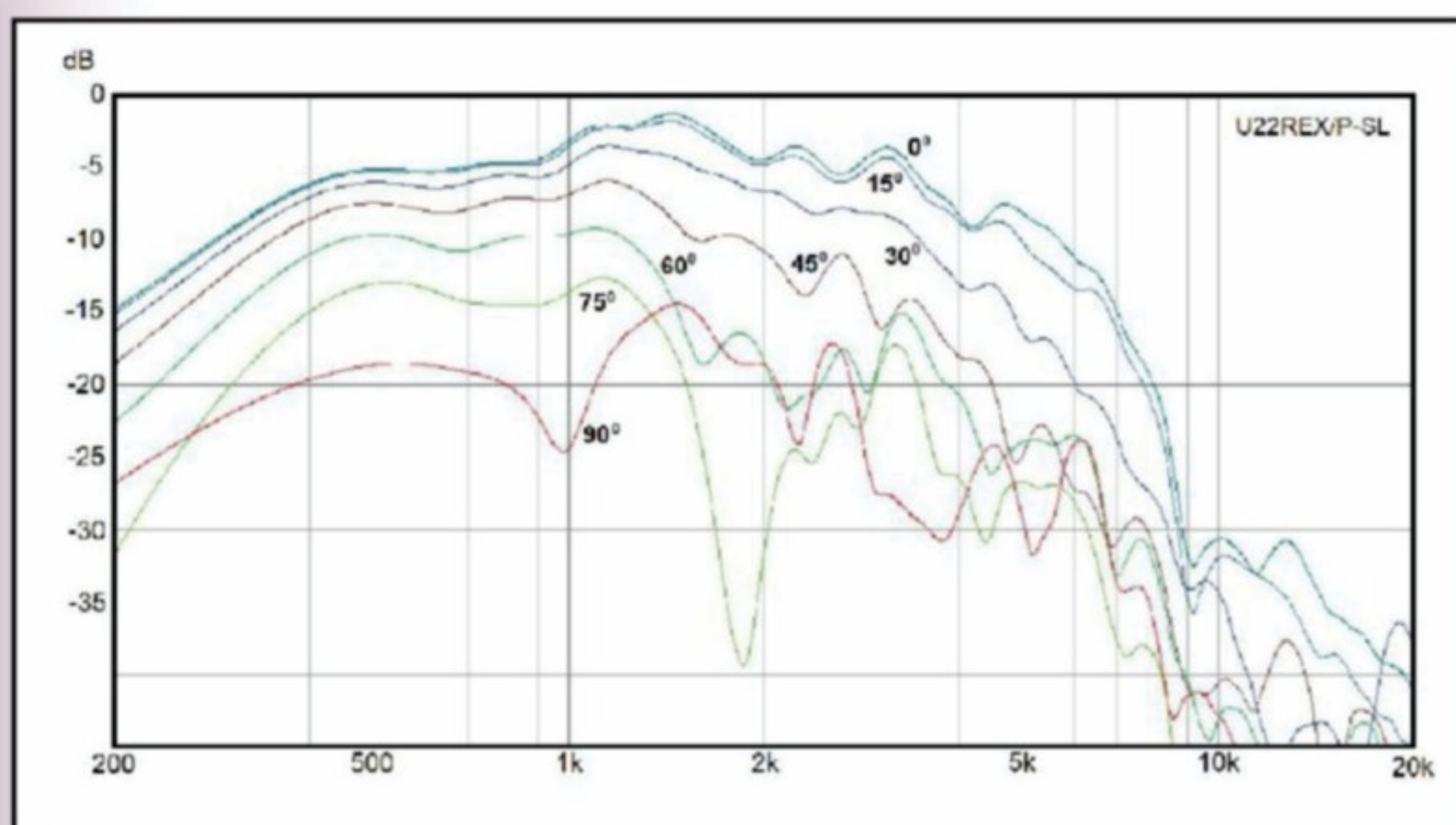


Figure 6: Polar response of the SEAS woofer

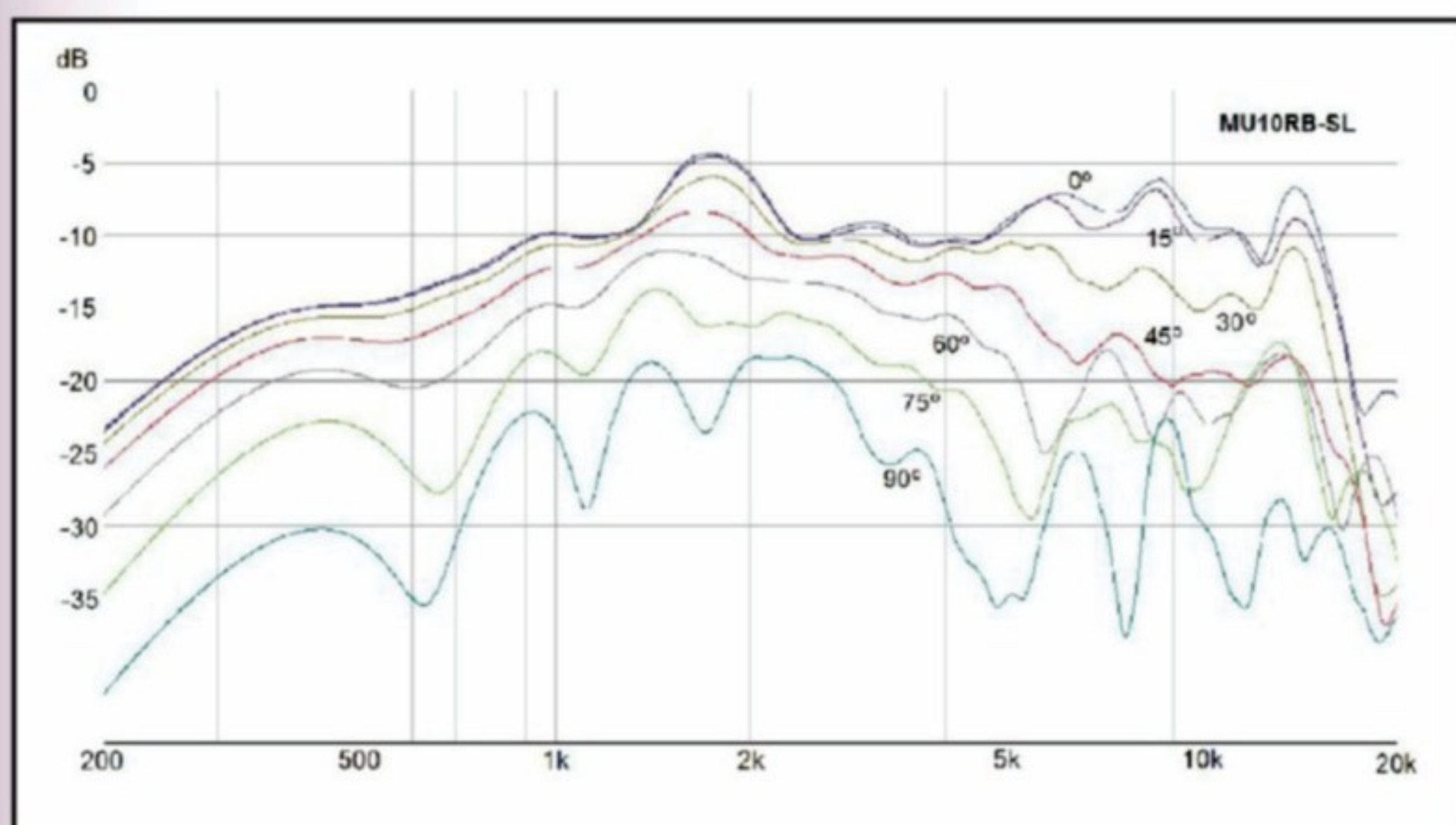


Figure 7: Polar response of the SEAS midrange

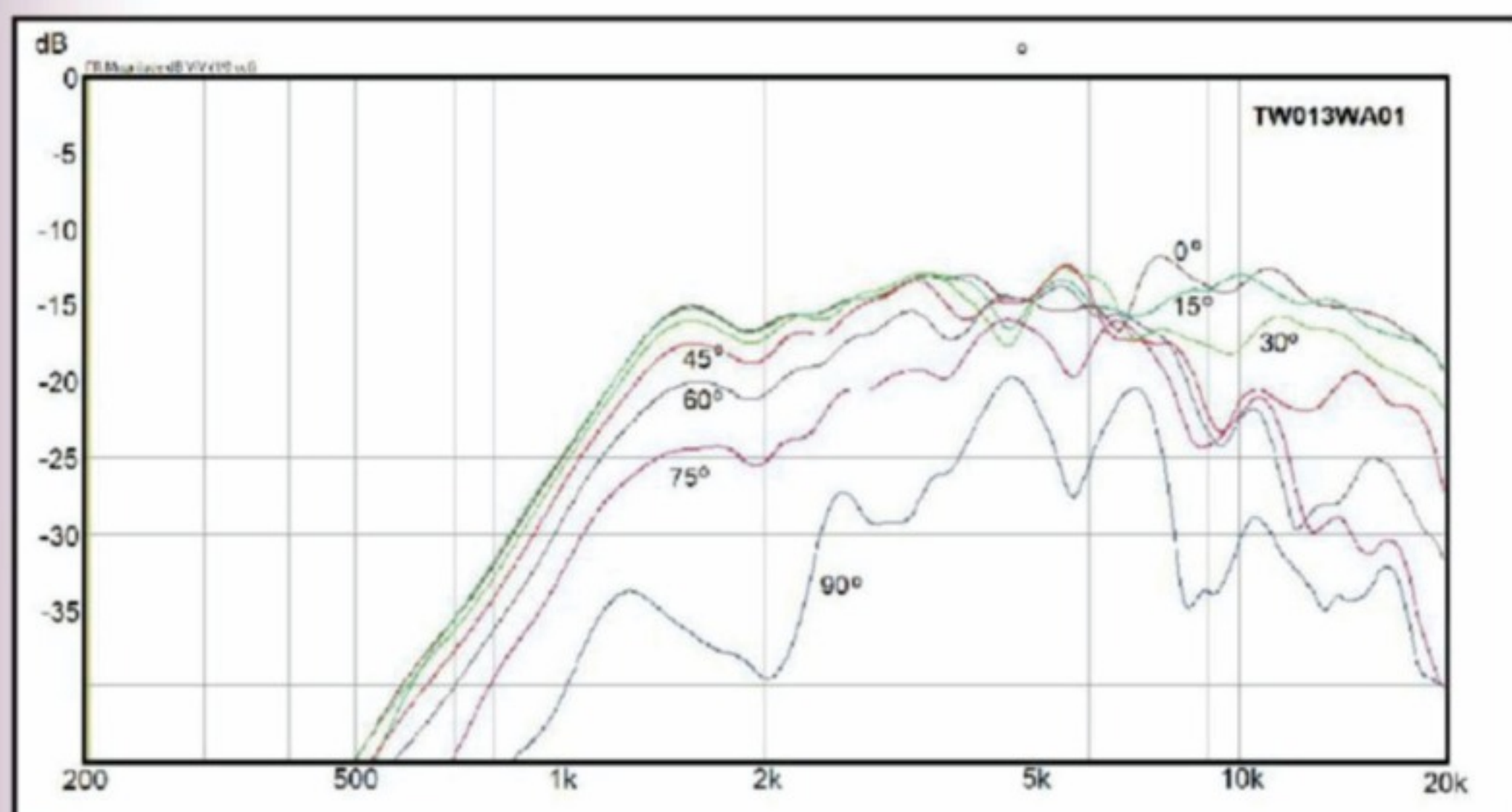


Figure 8: Polar response of the tweeters

I began the tests using ARTA software to measure the horizontal polar response of each driver. I defined the midrange driver's axis as the main axis of the loudspeaker. I measured all the responses without any equalization applied to the drivers. **Figure 6** shows the response of the SEAS woofer. **Figure 7** shows the response of the SEAS midrange driver, and **Figure 8** shows the response of the tweeters. Each figure shows seven measurements, taken on the main axis and off axis in 15° increments starting from 15° and ending at 90°.

For the woofer, the polar response is very well controlled up to about 1.1 kHz. Above this frequency, the polar response remains good but only up to 45°.

The polar response of the midrange is well controlled up to about 4 kHz, although above this frequency the measurements are still good but again up to 45°.

The tweeter has a very well controlled response below 3.5 kHz. Between 3.5 kHz and 7 kHz the response is very wide and then starts to gradually fall off as expected since the measurement is taken on the midrange axis and the tweeter is off axis.

Taking all the above measurements into consideration, I selected the initial crossover frequencies. Then each driver was equalized for a

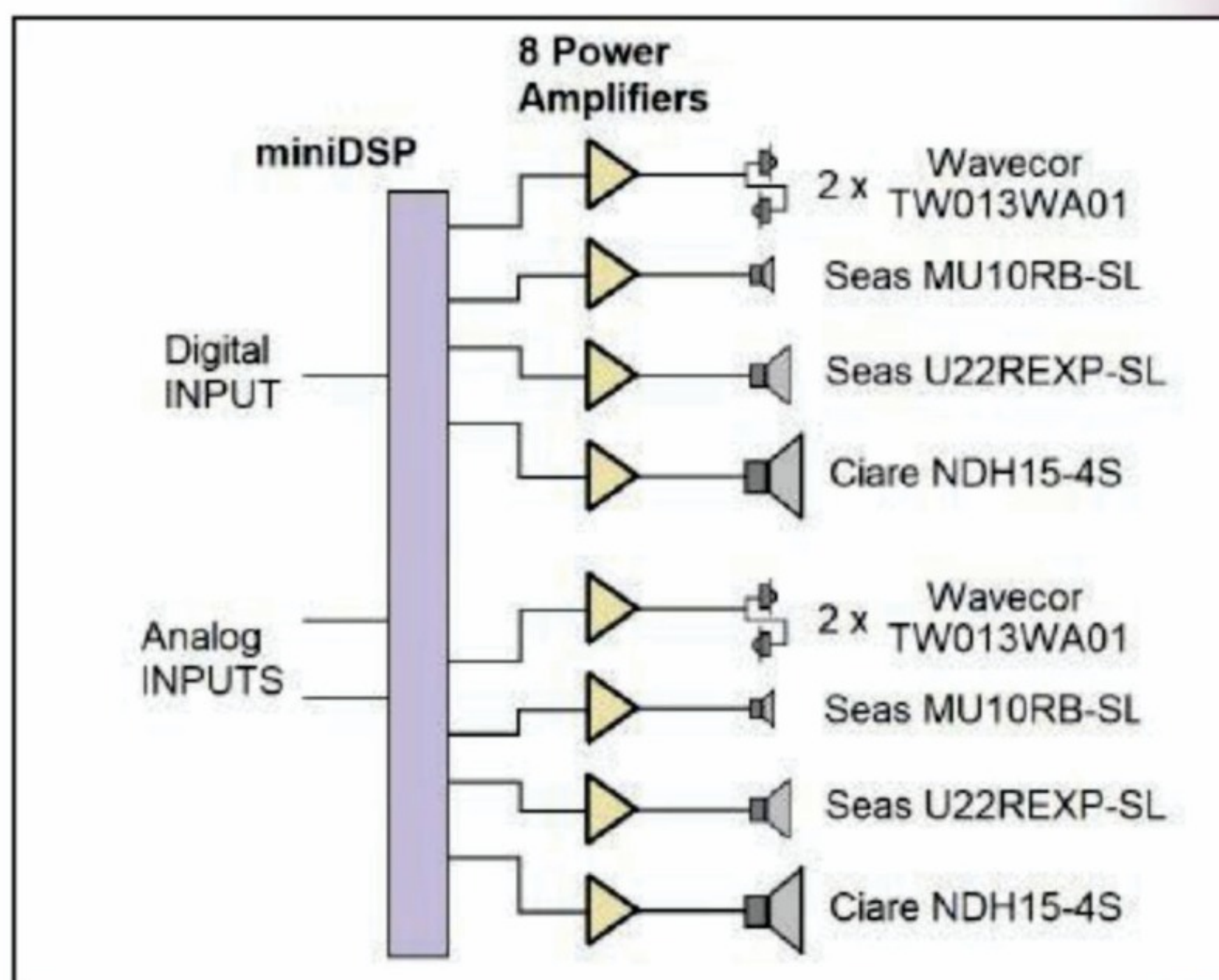


Figure 9: AXL loudspeaker's block diagram

About the Author

George Ntanavaras graduated from the National Technical University, Athens, Greece, in 1986 with a degree in Electronic Engineering. He currently works as a Technical Consultant for Products Development and Manufacturing. He is interested in the design of preamplifiers, active crossovers, power amplifiers, and most loudspeakers. He also enjoys listening to classical music.

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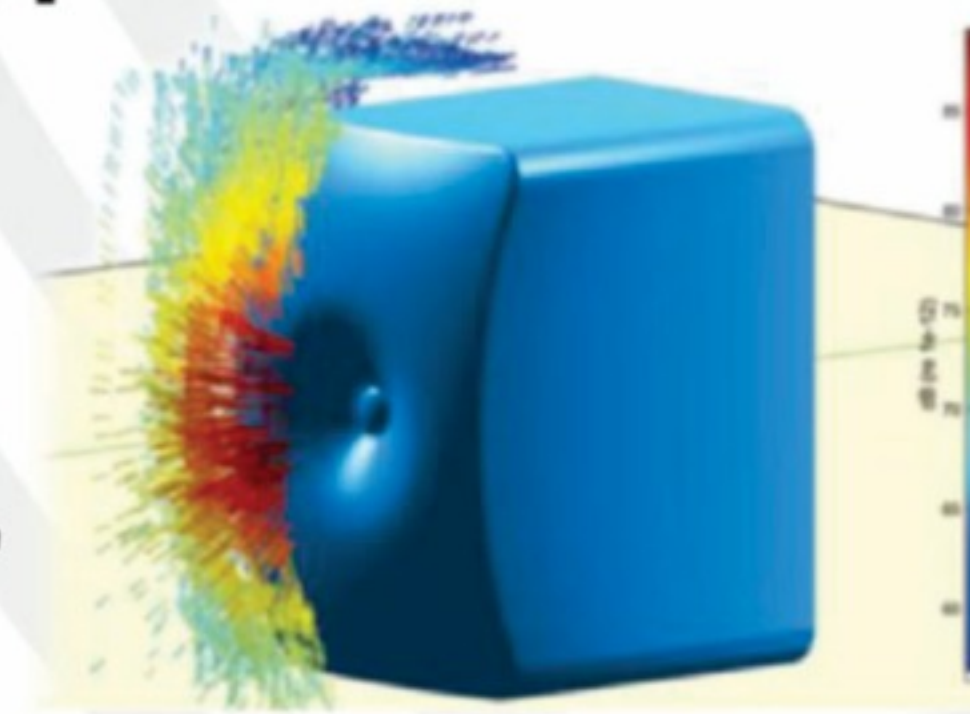
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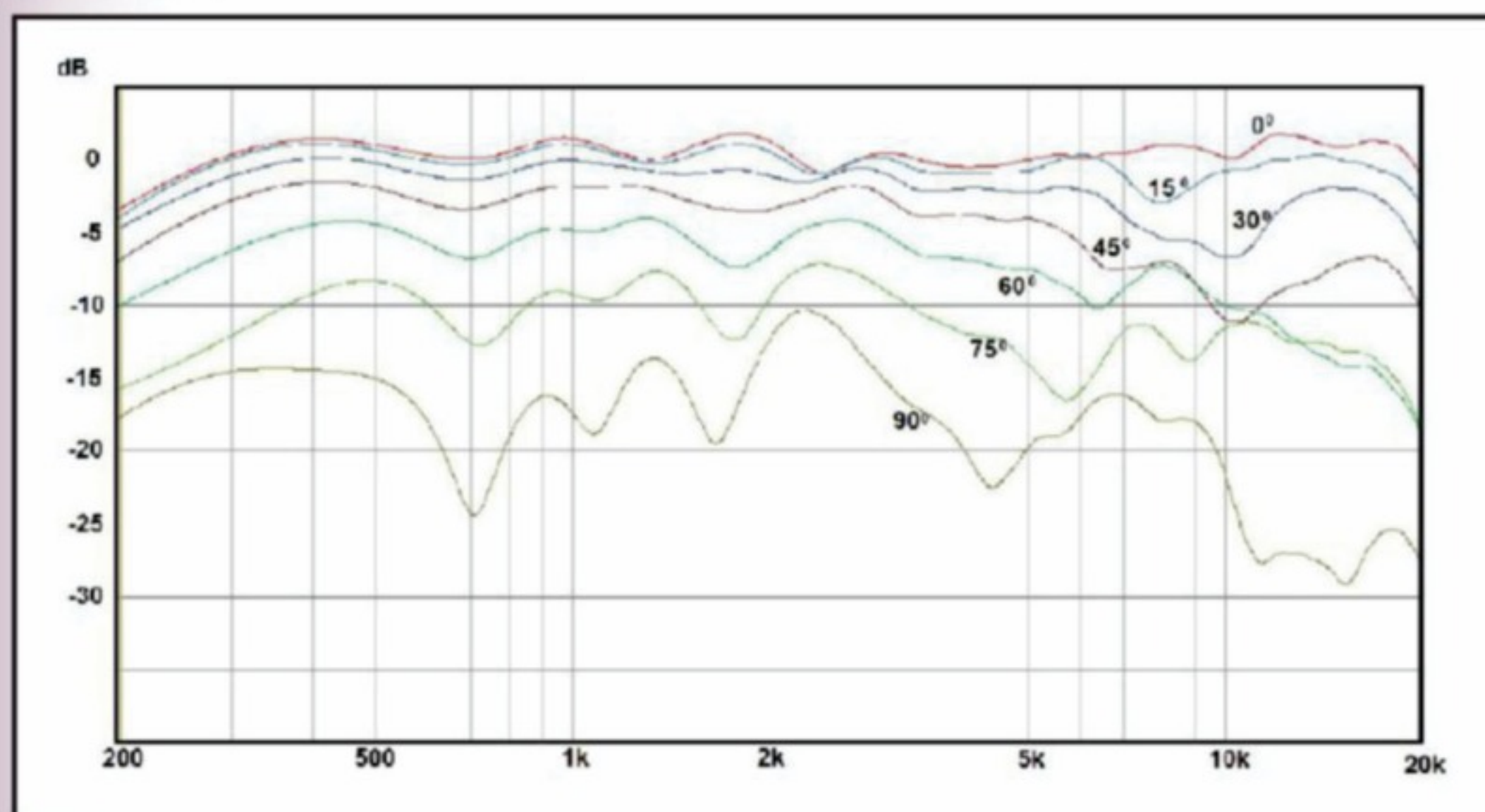


Figure 10: The horizontal polar response of the AXL loudspeaker

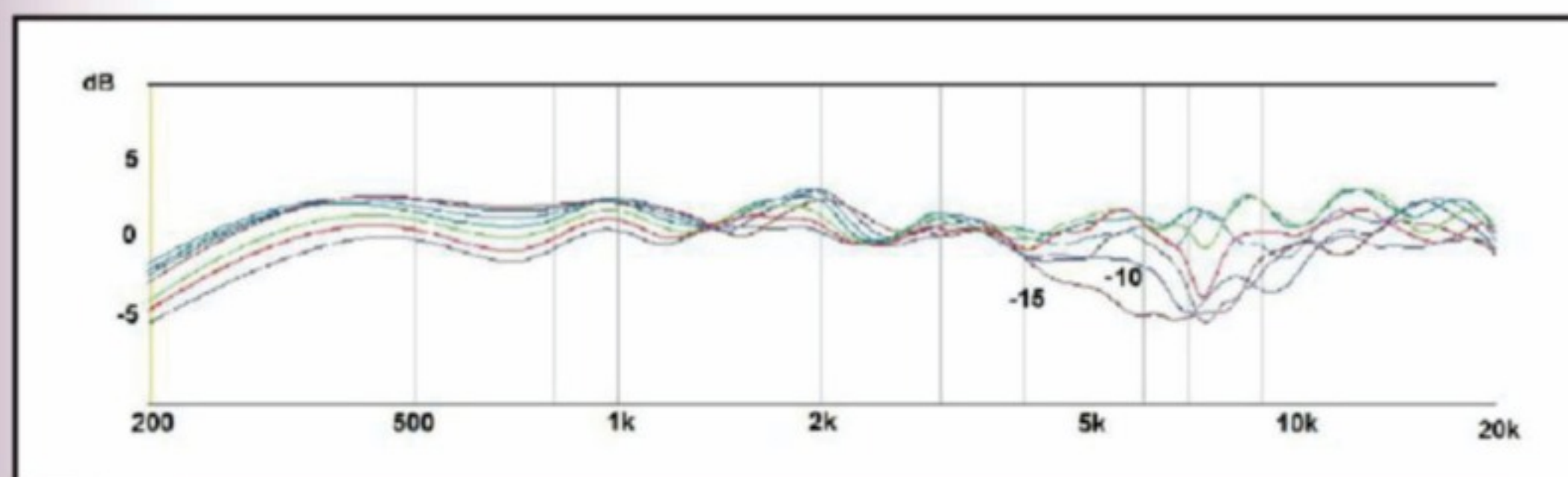


Figure 11: The vertical polar response of the AXL loudspeaker

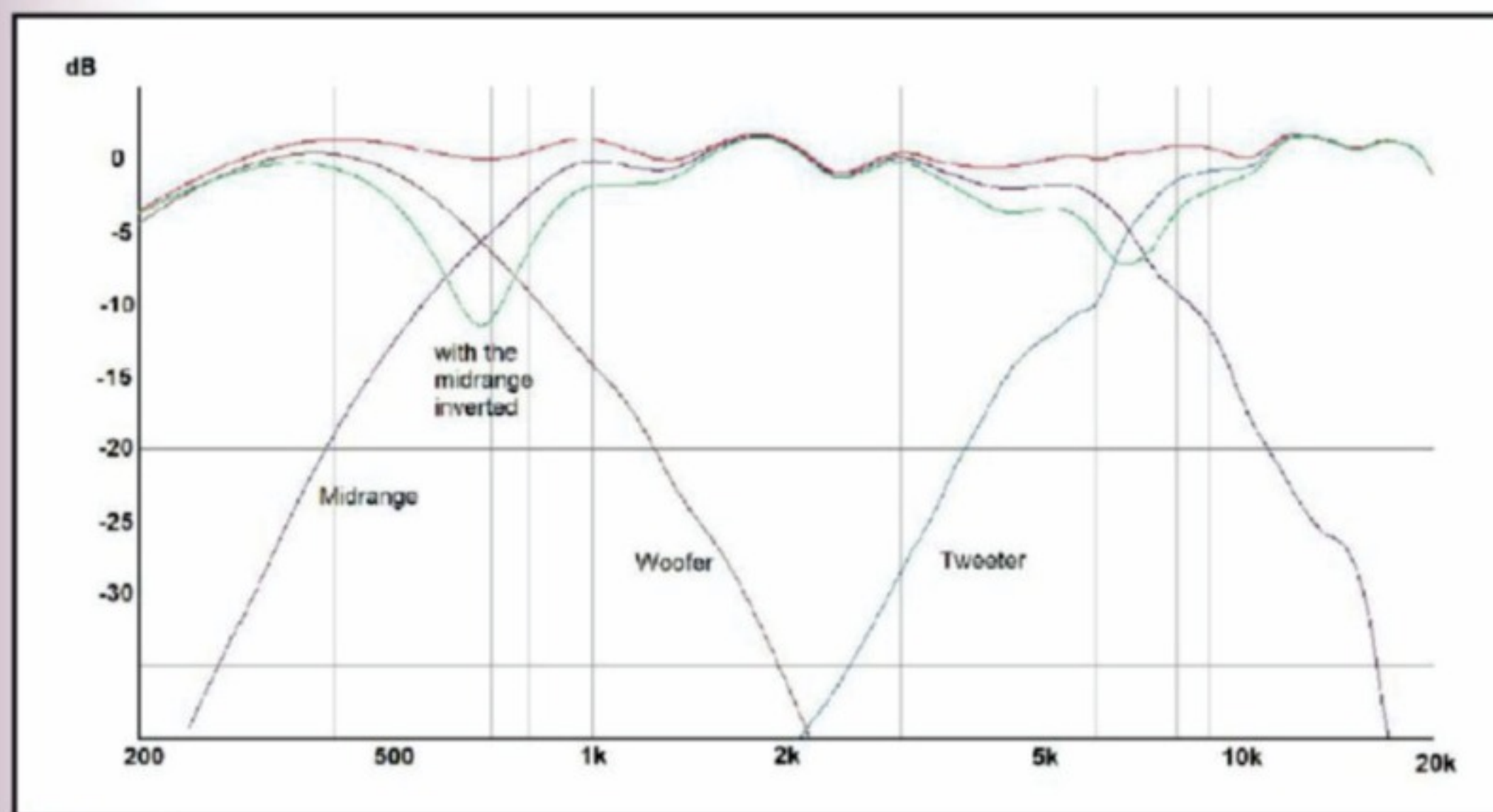


Figure 12: Acoustic response of the drivers

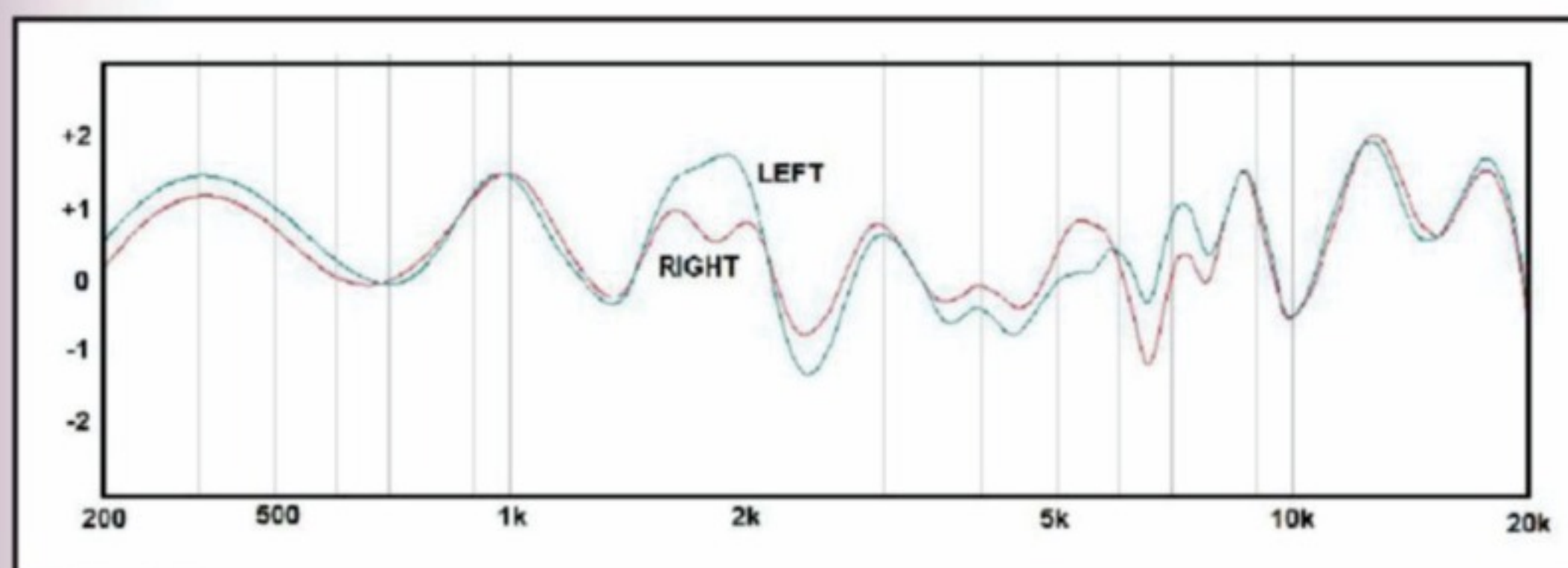


Figure 13: Left and Right channel frequency response comparison

flat frequency response at least one octave below and above the chosen crossover frequency. I again measured the polar responses of the combination of the two adjacent drivers and, where necessary, I modified the crossover frequency or changed the type of the crossover filter. With the miniDSP device, I was able to perform all the modifications very easily, but it was a time-consuming procedure. With an analog crossover, it would be very difficult to perform all these modifications.

The crossover frequencies that I finally chose after all those tedious tries were: 125 Hz between the subwoofer and the woofer; 700 Hz between the woofer and the midrange; 6.5 kHz for the midrange and 7 kHz for the tweeter between the midrange and the tweeter. I used fourth-order Linkwitz-Riley for all the filter types.

The subwoofer driver was also high passed with a second-order Bessel-type high-pass filter, which gave a -3 dB point at about 38 Hz and a -6 dB point at about 26 Hz. I did this for two reasons—to keep the excursion of the driver cone within a more safe area when the reproduction level is high and, most importantly, because I have found that the balance of low frequencies in my room was much better, probably due to the room gain at the lower frequencies.

For optimum design of the Linkwitz-Riley crossover, the drivers have to be made to radiate from the same acoustical plane—which should be parallel to the front baffle. Otherwise, the radiation pattern would shift away from the baffle axis in the crossover region. With an analog crossover (either passive or active) this cannot be easily realized because a lot of all-pass circuits are required. But with a digital crossover (e.g., the miniDSP device), this can be very easily realized. I adjusted the delay of each driver until I measured the greatest notch in the frequency response with the polarity of the midrange inverted. I set the delay to 0.4 ms for the woofer and the midrange and 0.44 ms for the tweeter. For the subwoofer, no delay was needed and it was set to zero.

Figure 9 shows a block diagram of the AXL system. The eight analog outputs of the miniDSP 4x10HD are connected to eight power amplifiers, one for each drive unit. The two amplifiers for the sub-woofers drivers have a power of 200 WRMS at 8 Ω , while the two amplifiers for the woofers a power of 60 WRMS at 8 Ω . For the midranges and the tweeters, I used low-power Class A amplifiers based on designs by John Linsley Hood.

Final Measurements

I performed a lot of measurements to verify the

completed loudspeakers and I will present some of them here. **Figure 10** shows the loudspeaker's horizontal polar frequency response with the reference axis taken at the middle of the midrange driver. The response is well controlled and very close to the ideal dipole response for most of the acoustic frequency range, but as expected the loudspeaker becomes relatively directional at the higher frequencies and some roll-off is shown.

Figure 11 details the vertical polar response of the loudspeaker. Seven measurements are shown, which were taken on the loudspeaker axis and at 5°, 10°, and 15° above and below the axis. The response is excellent up to 4 kHz, showing good integration between the SEAS woofer and midrange. A small suck out develops between 6 and 8 kHz and the response becomes excellent again up to 20 kHz.

Figure 12 shows the individual acoustic response of the woofer, the midrange, and the tweeter. The notches in the response with the midrange inverted indicate that the drivers are in phase in the critical crossover region.

Figure 13 compares the response of the Left and the Right speaker. The pair matching is excellent, though the left speaker has slightly more energy present around 1.8 kHz, and the right speaker has a small notch at 6.5 kHz. Probably both of them are not real and are due to minor reflections during the measurement of the two loudspeakers since they were not exactly in the same position.

Finally, the voltage as measured at the input terminals of each driver is shown in **Figure 14**. It is very interesting to note the extensive equalization for the subwoofer and the woofer drivers. The subwoofer within its operational range has a difference of almost 25 dB between 30 Hz and 120 Hz, while for the woofer the difference between 150 Hz and 700 Hz is about 15 dB. The increased voltage that is required to drive the tweeters is due to their in-series connection, which was necessary because of their nominal 4 Ω impedance.

Conclusion

The design, the manufacturing, and the measurements of the AXL loudspeaker was a very long journey and I spent a lot of time and effort so that the final results met my expectations. But, I think it was worth the effort. To my ears and to some other audiophiles who were invited to listen, they sound really great. 

Author's Note: I would like to dedicate this article to the memory of Siegfried Linkwitz, whose work was always an inspiration for me.

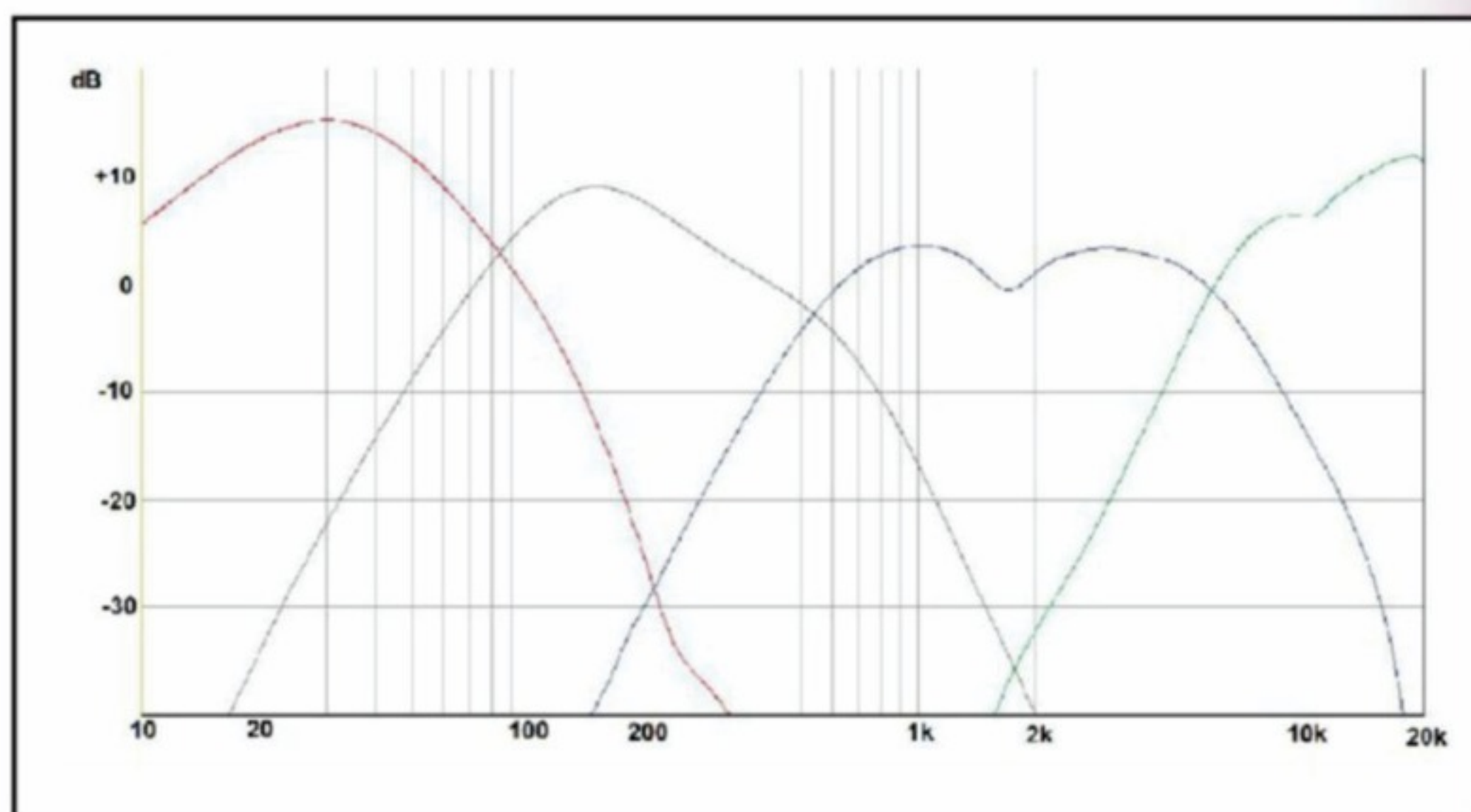


Figure 14: Voltage response at the input of each driver

Resources

Linkwitz Lab, (The website of Siegfried Linkwitz contains a lot of valuable information about dipole loudspeakers.), www.linkwitzlab.com/index.htm

G. Ntanavaras, "The Horizon Loudspeaker," *audioXpress*, September 2012.

Sources

SketchUp Make software

SketchUp | <https://help.sketchup.com/en/downloading-older-versions>

The Edge baffle diffraction simulator software

Tolvan Data | www.tolvan.com/edge/help.htm

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The Echelons

Go for the State-of-the-Art in DIY!

By
Dan Neubecker
(United States)

When I started my DIY speaker building adventure, back in 2005, I just hoped to build something that sounded good. I started by building some speakers designed by other experienced DIYers. After those efforts, I felt compelled to try my own design, so I purchased speaker design and measurement software and the gear to go with it and jumped into the fray with both feet. By 2011, with about a half-dozen well received designs under my belt, my confidence had advanced to the point that I was ready to attempt something “state of the art.” The result was the Echelons.



Can you really design and build a top-notch speaker in your garage? In this article, Dan Neubecker hopes to illustrate that it is possible, particularly if you are passionate about both audio and woodworking. DIY speaker building can be a compelling adventure, one that consumes much of your free time, but also brings ample rewards that include years of enjoyment and the satisfaction of having created something yourself.

In this article I will review the design and build process of these speakers and hopefully inspire readers to give this engaging hobby a try.

Conceptual Design

To start the design process, I identified a few things I wanted to accomplish. I wanted the speakers to be truly full range, without need of subwoofer support when used as mains in our home theater system. I quickly settled on a floor-standing, full-range three-way passive speaker that includes a subwoofer capable of handling frequencies up to a

300 Hz to 400 Hz crossover point; a high-resolution midrange that would sound effortless at all sound pressure levels (SPLs); and a tweeter that was accurate, non-fatiguing, and mated well with the midrange.

As it turned out, I already owned a pair of the the best possible subwoofer drivers for what I had in mind. The 12" TC Sounds TC1000 subwoofer was ideal for a sealed configuration, and modeled perfectly in a 90 ltr cabinet.

I had previously built a number of omnipole and open-baffle dipole speakers and understood that I preferred the expanded and enveloping soundstages at which those approaches excelled. At the same time, I found that those approaches could sometimes present a challenge when faced with limited placement options in smaller rooms.

I decided to try an open-back/cardioid midrange instead. That permitted me to adjust the amount of rear radiation that I wanted to allow by varying the amount and type of stuffing used in the open back tunnel. I was intrigued by what a large planar midrange might provide, but it needed to extend to 300 Hz to 400 Hz on the low end to work with the subwoofer driver. The Bohlender Graebener (BG) Neo10, a 10" planar midrange that was said to be capable of a crossover as low as 200 Hz, seemed to be the best available option.

At this point in the design process, I was not sure what I wanted for the tweeter, but felt it vitally important to have good directivity matching between it and the midrange at the crossover point.

With these decisions made, I began sketching design concepts, eventually developing them further in CAD. There were several driving factors behind the emerging cabinet design. Clearly, I had to be able to fit a large 12" woofer and 90 ltr of sealed space for it, plus room for a 10" planar midrange and the supporting tunnel exiting to the back of the speaker. The tweeter was still an unknown quantity, so I decided to take a modular approach and house the tweeter in a separate cabinet. This cabinet presumably would also be a logical location to house the passive crossovers.

My previous design and measuring experience had convinced me of the benefits of a cabinet shape with both tapered sides and large chamfers or facets. These features naturally smooth the frequency response and decrease the impact of edge diffraction on frequency response. Visually, I felt that a speaker that was larger toward the floor and narrower toward the top would appear both more stable and less massive when sitting in our living room. In addition, narrowing the cabinet as you transition up in frequency range would direct

more sound energy off axis than a wider cabinet, which should increase the apparent soundstage.

Finally, one of my goals was to design the front baffle in a way that allowed the three drivers to be close to equidistant from the listening position. This would potentially simplify the crossover design. A sloped back baffle was utilized to facilitate this goal.

With these guiding factors, I arrived at a conceptual design that I really liked (see **Photo 1**). Then, I proceeded to develop CAD plans for production. I also had to make some decisions regarding tweeter implementation before I moved on to the construction stage.

The Drivers and Their Implementation

Before we get into the details of the construction, I would like to include a bit about each driver and how it was implemented in the design.

The Woofer: TC Sounds' TC1000 12". The TC1000 is a high excursion (25 mm Xmax) 4 Ω subwoofer. It measures extremely well, with a virtually flat frequency response from 40 Hz to well beyond 1000 Hz. The 1 m/2.83 V sensitivity is around 87 dB using 0.5 Ω series resistance.

A sealed box was chosen, in part, for improved transient response, which I hoped would allow the large woofer to keep up with fast transients of the open back planar mid. The woofer is located near the floor and on a baffle that is 16" wide at its widest. This driver location and the baffle size limit baffle step losses.

With the woofer closer to the floor boundary, the typical null in the 100-to-200 Hz range that comes from a woofer placed higher on the baffle is reduced or entirely eliminated. Box modeling indicates an expected F3 of around 28 Hz. When including boundary and room reinforcement into the box model, we are looking at an F3 of below



Photo 1: After considering several guiding factors, I arrived at a conceptual design that I really liked.

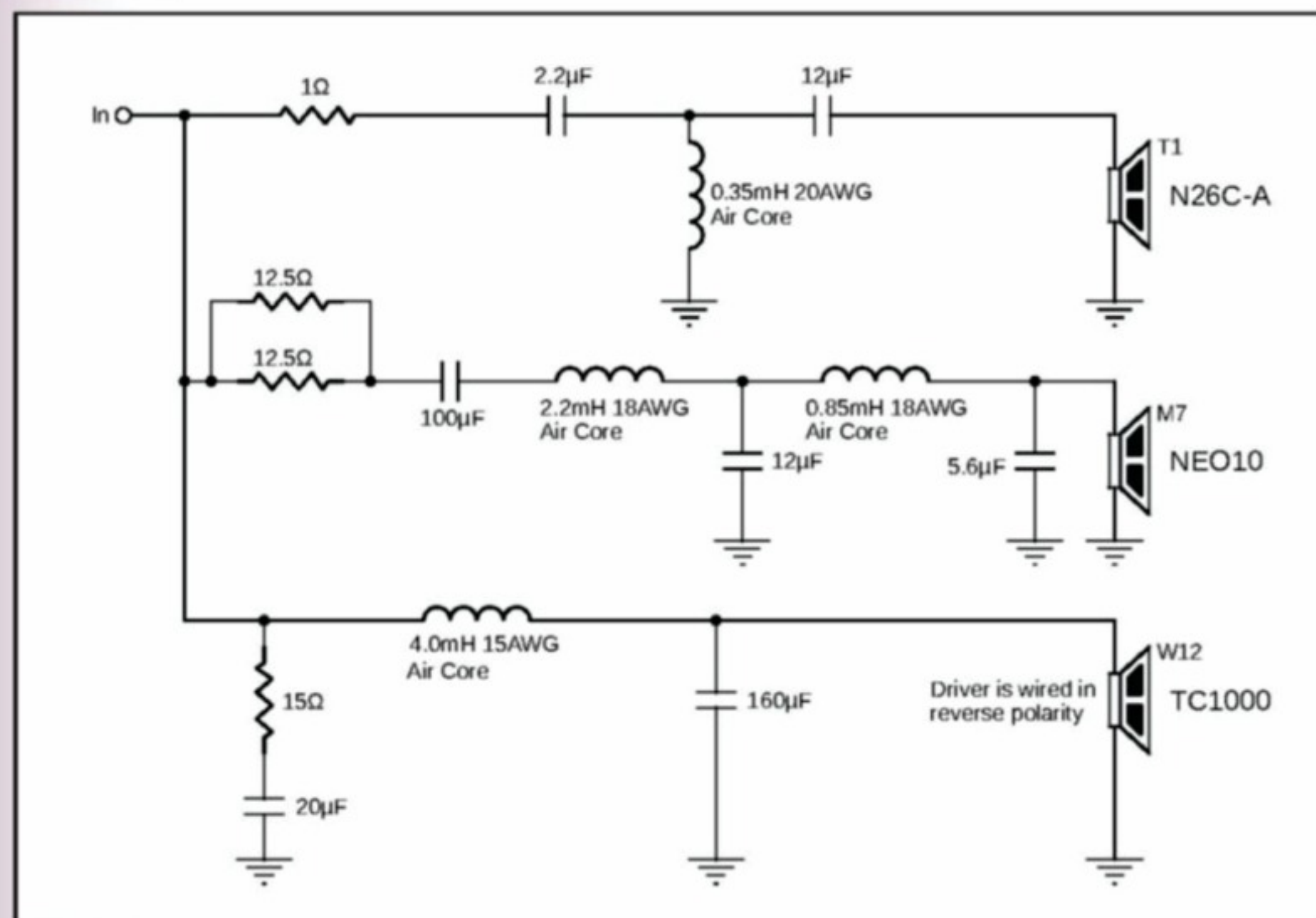


Figure 1: This is the final crossover schematic for the Echelons.

20 Hz with the driver never reaching excursion limits until well above 110 dB.

The Midrange: BG's Neo10 planar. The Neo10 is a large-format planar driver from Bohlender Graebener (BG). It has increased power handling, low-end performance and sensitivity over previous models. Being a planar driver, it has excellent transient response. When implemented in an open-back configuration, it really shines. Midrange energy, exiting the cabinet from the rear of the driver, can be attenuated through stuffing manipulation, and offers a substantial increase in soundstage width and depth, at no apparent loss of imaging. Midrange energy is not trapped inside a box and then reradiated back through driver membrane, out of phase with the direct acoustic output, which

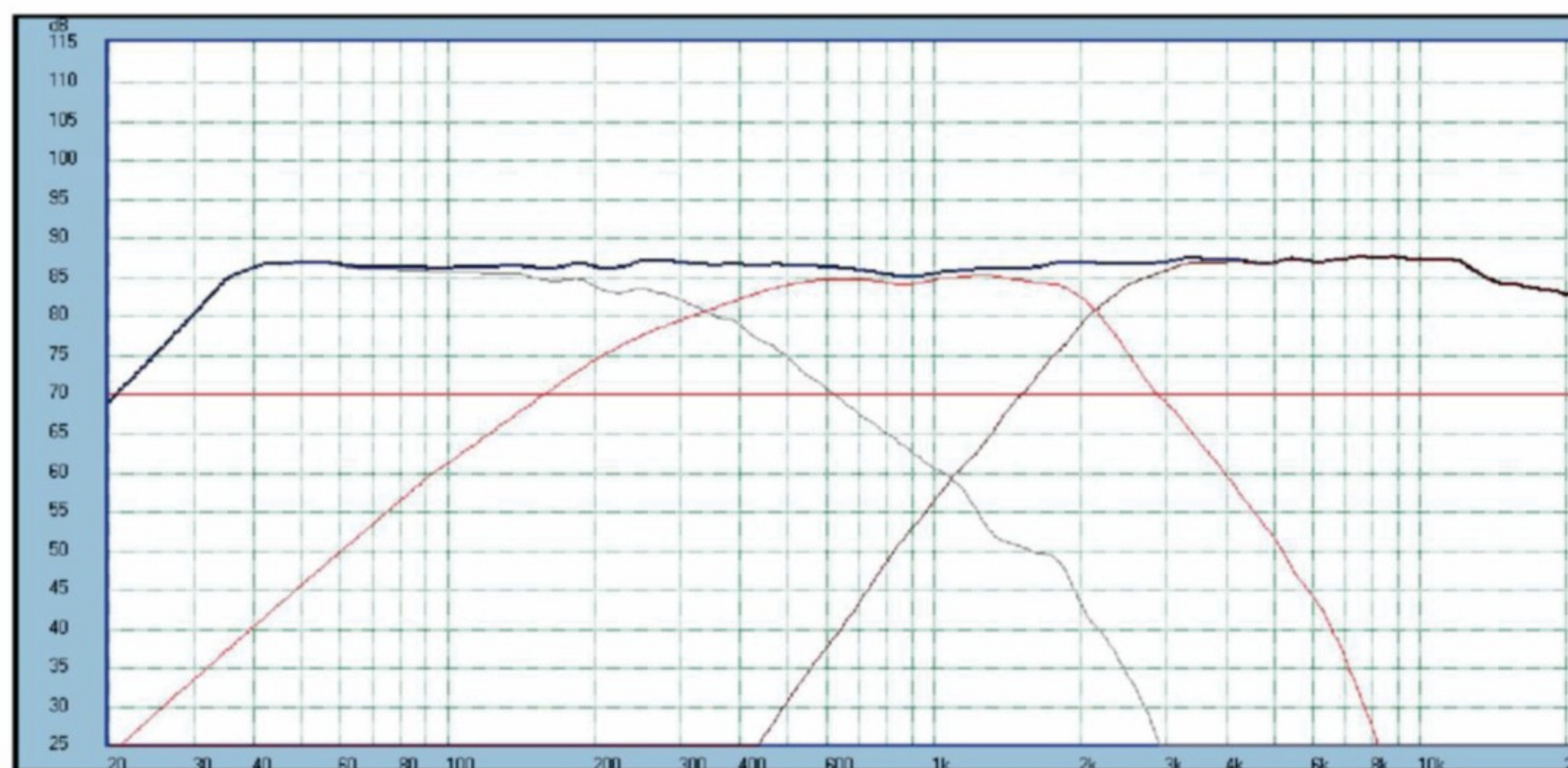
can sometimes be observed with sealed midrange enclosures. The Neo10, perhaps due to its fast transient response and open-back implementation, delivers a most realistic, live sound.

The Tweeter: Transducer Lab (TL) N26C-A. After much thought and a lot of waveguide testing, I decided to use the TL N26C tweeter in a custom waveguide. The N26C-A is a high purity, molded Al₂O₃ Alumina ceramic dome tweeter, with a response range of 950 Hz to 45 kHz. They were sold in pairs that were frequency matched to ± 0.75 dB. This already-low-distortion tweeter is implemented in an elliptical waveguide. The clear waveguide is approximately 1.5" deep $\times$ 5" tall $\times$ 6" wide and provides a low end boost exceeding 18 dB. When this boost is equalized out in the crossover, distortion is lowered even further while significantly improving tweeter headroom, allowing substantially increased SPLs without noticeable strain. The waveguide provides controlled directivity of tweeter output that matches perfectly with midrange directivity at the chosen crossover point. The result is an improved, flatter power response compared to traditional flush mounted tweeters. It also makes the speaker less sensitive to room placement.

Cabinet Design and Construction

The woofer was surface mounted, the midrange rear mounted, and the tweeter waveguide mounted. Combined with the sloping baffle, this allows for the driver voice coils to be equidistant to the listener's ear, which promotes improved phase tracking between the drivers over a wider range of frequencies and reduces or eliminates the need for asymmetric crossover slopes and more complex crossover designs. The final crossover schematic (see **Figure 1**) and modeled frequency response

Figure 2: The Echelons' modeled frequency response indicate crossover points of 325 Hz and 2200 Hz.



(see **Figure 2**) indicate crossover points of 325 Hz and 2200 Hz. The woofer to midrange acoustic slopes are approximately 15 dB/octave, halfway between the second and third order. The midrange to tweeter acoustic slopes are approximately 24 dB/octave. The response models at ± 1 dB from 40 Hz to 14 kHz, where the tweeter begins to roll off a bit in the upper half-octave, as show in Figure 2.

Due to the increased rear radiation of the open-back mid, the midrange is slightly depressed in the crossover design. The relative level of the mid is somewhat adjustable to fit an individual's sound or musical tastes, to adapt to their room response or to speaker placement. This is done by altering the amount and/or type of stuffing in the open-back enclosure.

Two pairs of binding posts are provided on the rear of the cabinet. This will allow for bi-amping of separate woofer and midrange/tweeter crossover networks. It would also enable future use of digital signal/room equalization products to help compensate for individual room and placement conditions.

The Woofer/Mid-Box Construction: The lower cabinet is constructed using MDO plywood. This



Photo 2: I laid the parts for the sides, top, and bottom of one speaker end to end.

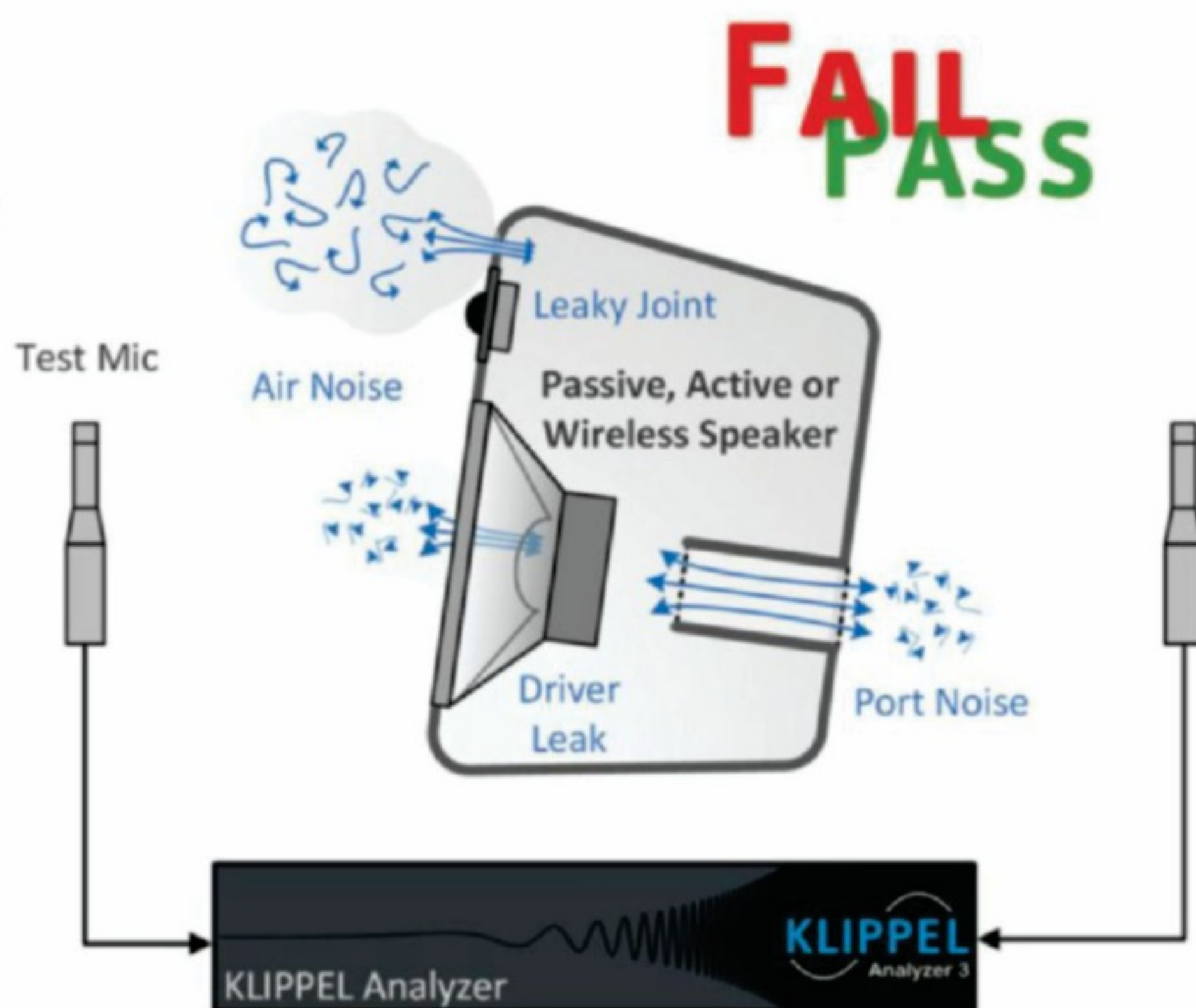
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Photo 3: The front panel is placed within the dado as it is folded to ensure a square result.



Photo 4: A backing piece is placed behind a laminated baffle that is glued to the bracing infrastructure.



plywood has a thin layer of MDF-like material on the outside layer that does not chip out or splinter when cut and makes it easier to paint or veneer than other plywoods. It is also much lighter than MDF. The joints around the sides and top are all miter joints, so there is no telegraphing of the joints through the paint. The rear panel is dado'd into the sides and a layer of 10 mil paper back veneer was added over the back to reduce telegraphing of these joints.

Photo 2 shows the parts for the sides, top, and bottom of one speaker end to end. The joints are carefully placed together and taped, then glue is applied, and the entire outside shell folded up to form the box, then clamped with strap and bar clamps until the glue is set. The front panel is placed within the dado as it is folded to ensure a square result, though no glue is applied at this time so it can be removed for installation of the bracing matrix (see **Photo 3**).

The bracing matrix consists of 0.5" closely spaced and interlocked window-type bracing to ensure that unsupported panels are small, approximately 5" or less. The bracing system is tied together vertically and horizontally in the box. One-quarter-inch-thick rubber tiles have been adhered to the side walls to add some mass and further diminish potential unwanted panel vibrations.

There is a 0.5" backing piece behind a laminated baffle that is glued to the bracing infrastructure (see **Photo 4**). The laminated baffle itself is 1-1/2" thick, made from strips of 3/4" MDO plywood glued together with the edge grain out. It was then planed (at a local mill) to 1-3/8" thick. The drivers are attached directly to the removable, laminated front baffle, which is kept floating above the speaker body with 0.75" wide x 3/16" thick weather stripping. This less rigid attachment is intended to limit vibration transfer from the baffle to the box and the removable baffle allows access to the rear mounted midrange driver.

Tweeter Box Construction: The tweeter box is constructed using the same MDO plywood, with the exception of the curved top and flat side extrusions. The top was created by laminating six pieces of 1/8" Masonite, using strap and traditional clamps to form it over the box. Titebond III was utilized throughout.

The tweeter box is held in place over the woofer/mid box using cap head screws and threaded inserts, with the screws accessible from inside the midranges tube (see **Photo 5**). There is a 0.25" piece of rubber tile spacer between the woofer/mid box and the tweeter box to help isolate it from vibrations. The woofer and mid/tweeter crossover are configured on separate boards that are screwed to the top of the woofer/mid box through the rubber tile (see **Photo 6**). The front laminated tweeter baffle is also removable to enable access to the rear-mounted tweeter.

Cabinet Finish

After seeing the sanded, edge-glued plywood front baffle, I decided to just clear coat it. It ended up looking similar to an exotic Zebrawood. The clear tweeter waveguide keeps the wood visible top to bottom.

Since the laminated baffle is quite busy, I felt a simple painted finish would look best and give the speaker a fresh, contemporary look. I used a slightly off-white, oil-based paint for the painted surfaces, once it was sanded and primed. I applied multiple layers and wet sanded it to eventually build up an extremely smooth, high-gloss finish (see **Photo 7**).

So, How Do They Sound?

To this day, I believe the Echelons are my personal best and are still the favorite speakers I've owned. I have included some examples of comments posted by others after two of the DIY speaker events where they were auditioned and/or competed. These kinds of comments are great motivators and help keep the creative fires burning for later projects.



Photo 5: The tweeter box is held in place over the woofer/mid box using cap head screws and threaded inserts, with the screws accessible from inside the midranges tube.



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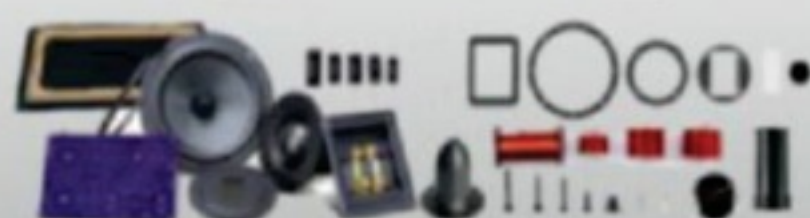
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At InDIYana 2012:

From Ben Shaffer, "Dan's "Echelon," IMO, stole this show with something that could easily sell commercially. Aesthetic content was up there with Marten, Coltrane, and the Kharma Exquisites. The clear-acrylic Pellegrene waveguides really made them stand out. The Transducer Labs tweeters, I feel, sounded very clean and articulate, the BG Neo10 had resolution that needs to be heard at the \$170 price, and the TC woofers were obviously capable. The mid was in an open-back scenario, but I didn't feel it was as inaccurate as some other open-back mids in terms of pinpoint definition."

From Brian Keene, "I am so glad that you had the chance to demo the Echelon twice and this is why (eventually) it really made my jaw drop. In the first audition, we kept the levels the same as all the other demos (around 75 dB to 80 dB). The Echelons sounded very neutral to me. I was pleasantly surprised with how well they imaged even though I was off to the right-hand side. Thanks Dave for the terrific wave guide!! I was all geared up for some

'in your face' bass, but that didn't happen....I was disappointed. It's not to say at all that the Echelon didn't sound good....It did, in a larger than life way. On the second audition, when Rory (I think) pumped up the volume and we were hitting 97 dB, is when these puppies impressed LARGE. Effortless, balanced, full, non-fatiguing, I don't know what else to throw in here.....I'm horrible with speaker adjectives. At any rate, they didn't sweat at all and I got all the 'bass in my face' that I ever wanted from the Echelon when the volume was turned up a bit, and it never got muddled or sounded stressed, etc. You guys who were witnessing this on the video stream commented that the mics were clipping....they were. The RTA even started to throw up overload messages as we approached 100 dB."

From Rory Buszka, "My favorites of the day (in order of favoritism): 1. Dan Neubecker's Echelon: These utterly ran away with the show. The combination of a waveguide-loaded electrodynamic tweeter with the planar mid worked surprisingly well, with no discernible discontinuities. Bass from the TC-Sounds woofer went deep with weight and authority at all volume levels, and the Neo10 planar mid was sublimely realistic. Overall, the speaker was capable not only of a very accurate yet listenable performance, but also of creating an almost tactile experience across the entire frequency range. A second listening session with peak levels of 95 dB at the seats led to more superlatives: spectacular and thrilling. The sound was never harsh or piercing, just unbelievably loud and clean, with no shift in tonal character. If these speakers were to be offered for sale to high-end clientele, they could command a price between \$65,000 and \$80,000 for the pair, and possibly still be called a 'bargain' in that market at those prices"

At Midwest Audio Fest 2012:

The Echelons were awarded first place in the "over \$200 category at the 2012 competition and went on to be featured on the cover of the 2013 Parts Express catalog.

From Jeff Bagby, "I want to close by calling out a couple of designs that really impressed me in one way or another. First, this was the second time I listened to Dan's Echelons—without a doubt one of the best sounding speakers I have ever heard in my life. It is certainly on the same plane or higher as the Salk Soundscapes or Archos, two speakers that I was involved with personally."

Conclusion

So, can you build a top-notch speaker in your garage? I believe the answer is yes. The Echelons are only one example. I see numerous examples

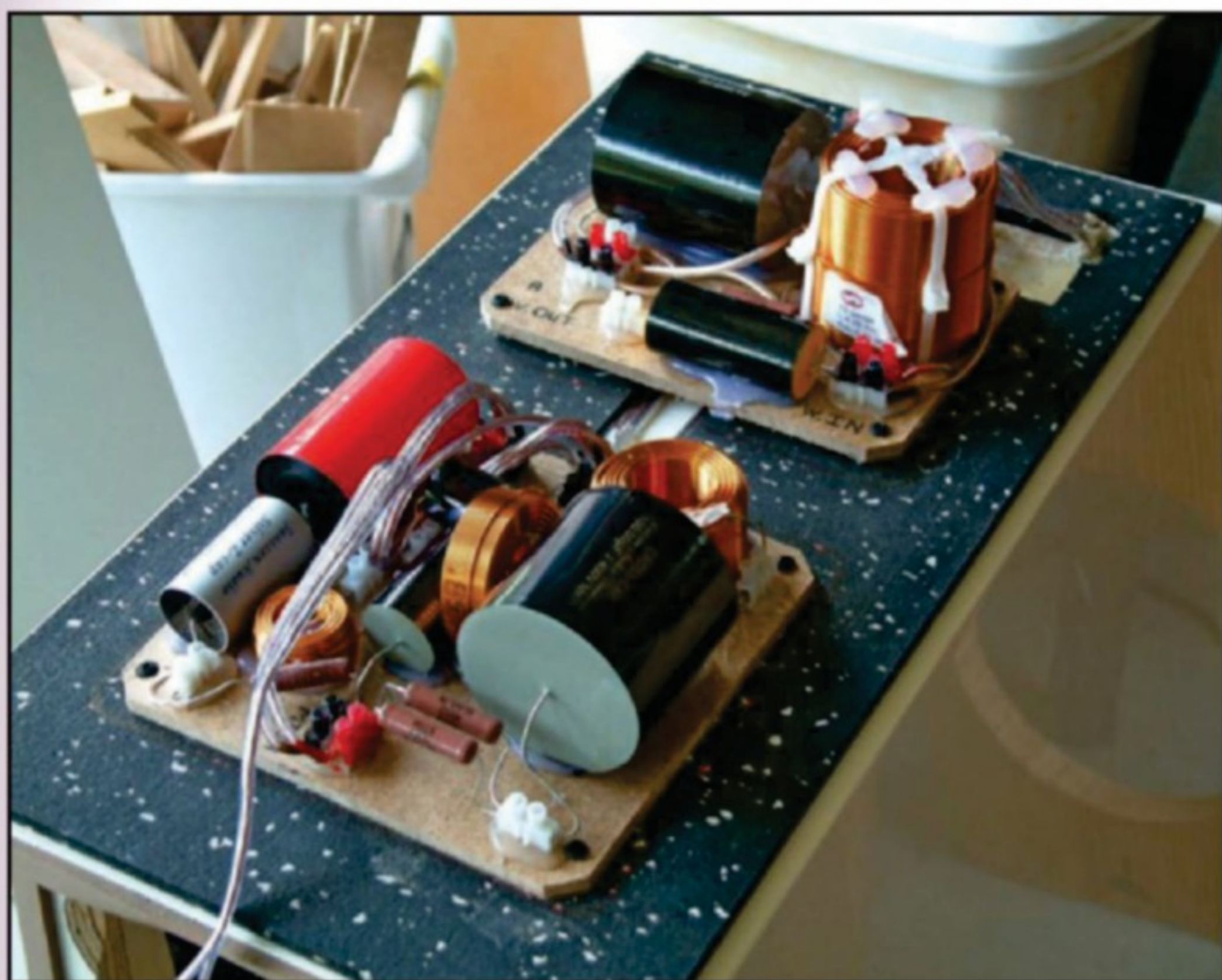


Photo 6: The woofer and mid/tweeter crossover are configured on separate boards that are screwed to the top of the woofer/mid box through the rubber tile.

About the Author

Dan Neubecker is a Landscape Architect and graduate of Michigan State University. He has no formal training or background in electronics, but he has had a passion for audio since his high school days. Dan has designed and built many award-winning DIY speakers since his introduction to the hobby in 2005 and assisted as crossover designer for numerous others. He enjoys DIY speaker design and building, golf, golf club-making, and photography as hobbies.

at every DIY speaker event. With some relatively inexpensive (or free) software and measurement gear, a passion for audio, dedication to learning how measure, design, and build a quality pair of speakers and crossovers, support of a very knowledgeable DIY community, and either some reasonable level of woodworking skills (or a friend who has them!), you might be surprised by what you can accomplish. Welcome to the world of DIY speakers! 📧

Author's Note: I received a great deal of support from the DIY community. Thanks to all who lent a hand with this project. Fellow DIYers Dave Pellegrine and Dan Poinsett provided waveguides for testing with various tweeters. One of Dave's was implemented in the Echelons. Thanks to Ben (Wolf) Shaffer for suggesting the name, Echelon.



Photo 7: I applied multiple layers and wet sanded it to eventually build up an extremely smooth, high-gloss finish.

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Purifi Audio

A Straight Wire to the Soul of Music

As *audioXpress* previously reported, Purifi Audio is a new venture involving several audio industry veterans. The Netherlands Audio Engineering Society (AES) section invited two of the company's founders, Bruno Putzeys and Lars Risbo, for a technical update on their plans, and they graciously agreed to a presentation on June 13 at the Royal Conservatory of Music in The Hague. Our Technical Editor Jan Didden attended and reports. In a sidebar to this article, J. Martins shares more information about Purifi Audio's business strategy and measurement methods.



Photo 1: Bruno Putzeys is one of the founders of Purifi Audio (Photo courtesy of Bert Kraaijpoil, AES Netherlands)

By
Jan Didden

audioXpress Technical Editor

Bruno Putzeys (shown in **Photo 1**) kicked off the event with a technical presentation on his new Class-D creation. His NCore amplifiers were touted to be more linear than any other amplifier in any other class, but some recent products challenged that statement, so it was time for a next leap forward. Sporadic reports of a sort of "granularity" in the sound reproduction also prompted an investigation

into whether this indeed happens, and if so, what would be the cause. After a long and winding road, Putzeys finally found a culprit: hysteresis in the ferro-magnetic material of the amplifier output filter coil.

Figure 1 highlights the issue. We all know the familiar B-H curve of ferro-magnetic materials. We tacitly assume that the signal traverses the B-H curve in each direction as given in the graph. What was found was that the flux at a specific point on the curve can be different depending on how you arrive at that point. For instance, following the path 1 through 6 takes you through points 2 and 5, which are actually identical points on the curve but with different flux values! So there is an element of hysteresis, memory if you like, which causes strong nonlinearity. Although the feedback loop decreases all nonlinearities it encloses, if the error is large enough it can make itself heard in the output signal. This also suggests the solution: just increase the loop gain (that is, the amount of feedback)!

The crux for increased feedback is a tailored compensation loop, but to be able to design that you need to be able to model how the amplifier (and its output filter with the output coil) varies in gain and phase at any load and any level within its working envelope, and adapt the feedback/compensation loop accordingly. That appeared surprisingly hard for a self-oscillation Class-D amplifier. For instance, the

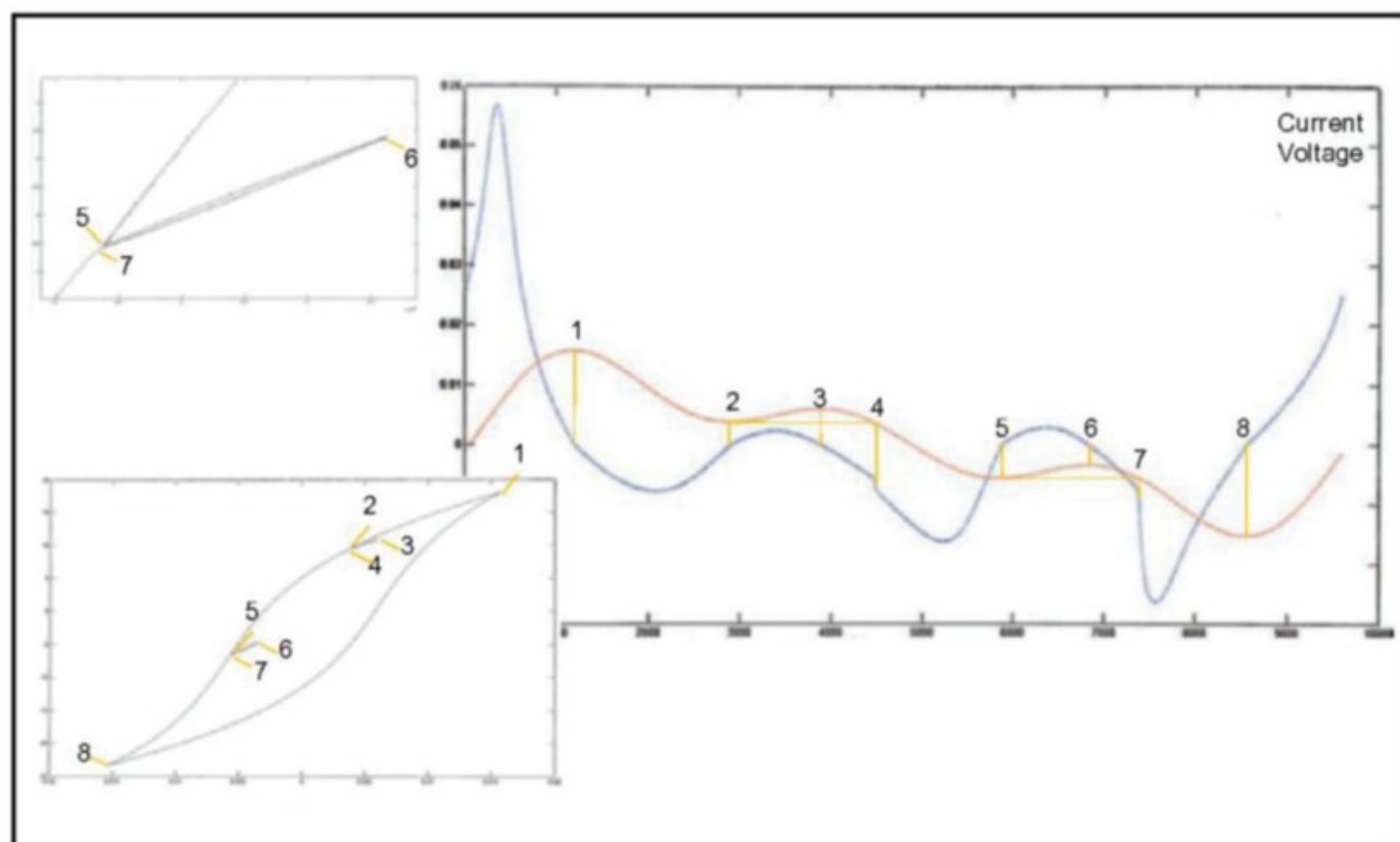


Figure 1: The magnetic flux depends not only on the point on the BH curve, but also on where at which point you were before—there is a memory effect of sorts.

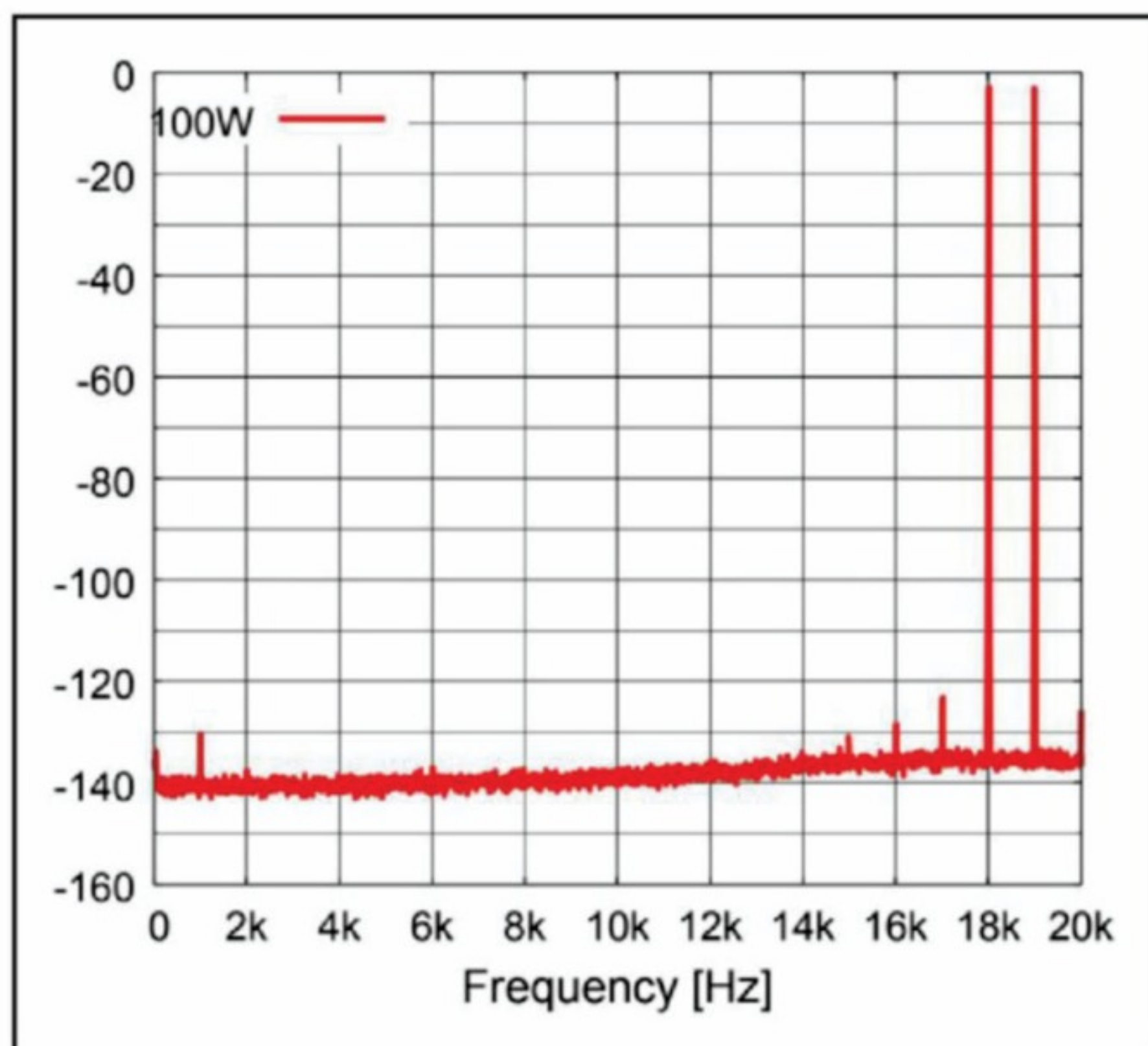


Figure 2: Intermodulation distortion at 100 W output

amplifier's "gain" is different at a rising edge of the switching waveform compared with the "gain" at the falling edge, so you should somehow account for that in shaping the loop. As Putzeys explained, you can consider the self-oscillating amplifier as a sampled system with two separate regular sampling trains, one for the rising and one for the falling edge, with the gain at each sampling point being different and with a time offset corresponding to duty cycle.

The new amplifier loop can now be analyzed like a noise shaper, with nonlinearities in the audio band strongly suppressed at the expense of amplifying errors far outside the audio band (see **Figures 2–5**). The amplifier self-oscillates where that gain becomes infinite. Further details were—understandably—not given but a few performance graphs speak loud and clear.

Risbo Discusses Modern Speaker Drivers

After the break, Lars Risbo (shown in **Photo 2**) took the floor with several observations about modern speaker drivers. (In case you were wondering about the unusual team up of a speaker designer with an amp designer: the magnetic hysteresis distortion—the memory and crackling noise problem described by Putzeys—is also a big issue for speaker drivers!). With the move to smaller speaker drivers, the stroke of the drivers had to be increased to maintain acoustic output. But that move also increased nonlinearities and Risbo has done a lot of research targeted to make a small, long-stroke driver sound as good as the traditional large-area short stroke drivers of yesteryear. Intriguingly, although an increase in the second harmonic distortion is expected when moving to longer stroke,

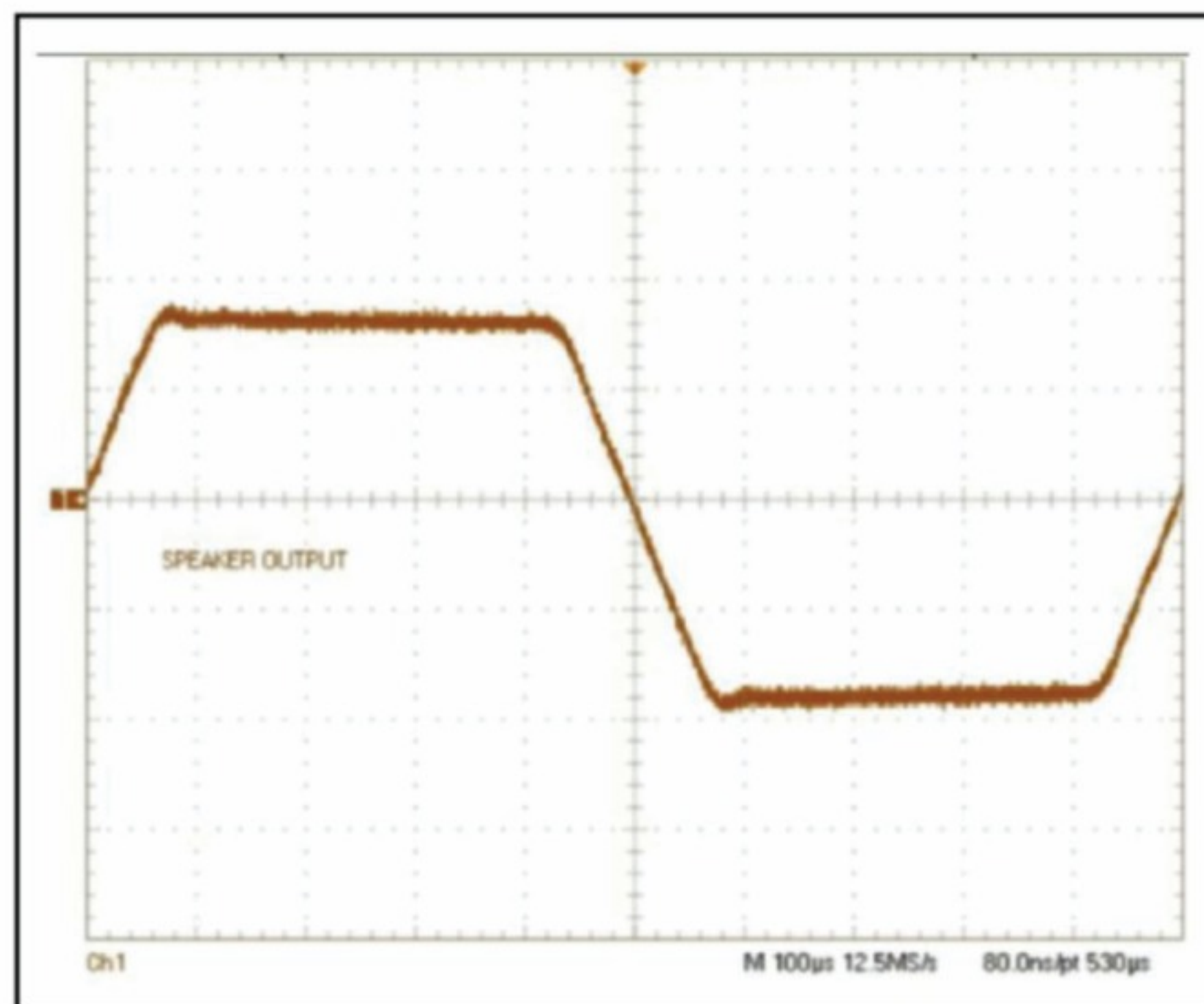


Figure 3: Clipping and clipping recovery is flawless.

above F_0 that increase was much higher than what is predicted by the (non-symmetry) of the B-L curve. Why is that?

And here again, magnetism and its many shapes rears its head. Risbo first explained that the nonlinear component of the force is already there before the magnet is added. Voice coil inductance is dependent on the position of the voice coil in the gap due to

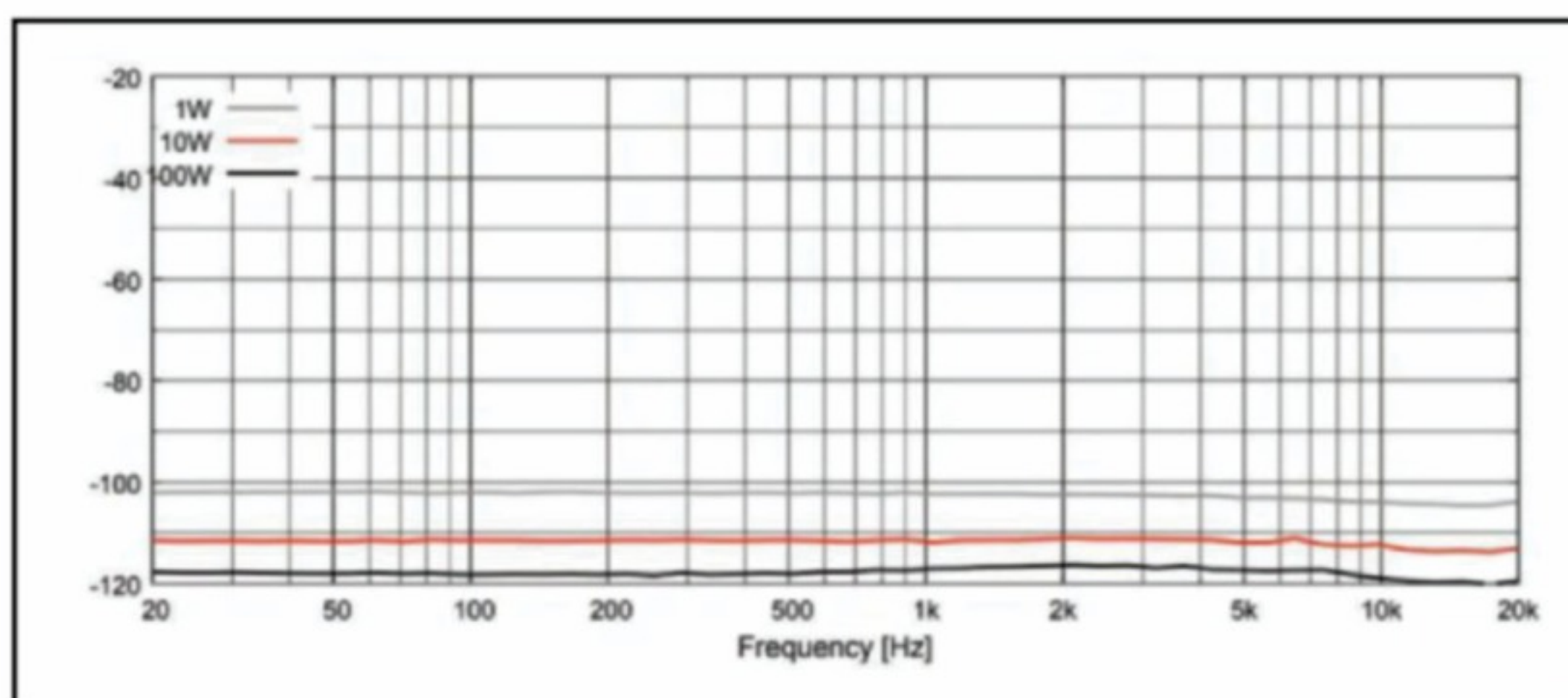


Figure 4: Distortion versus frequency at several output powers is low and flat.

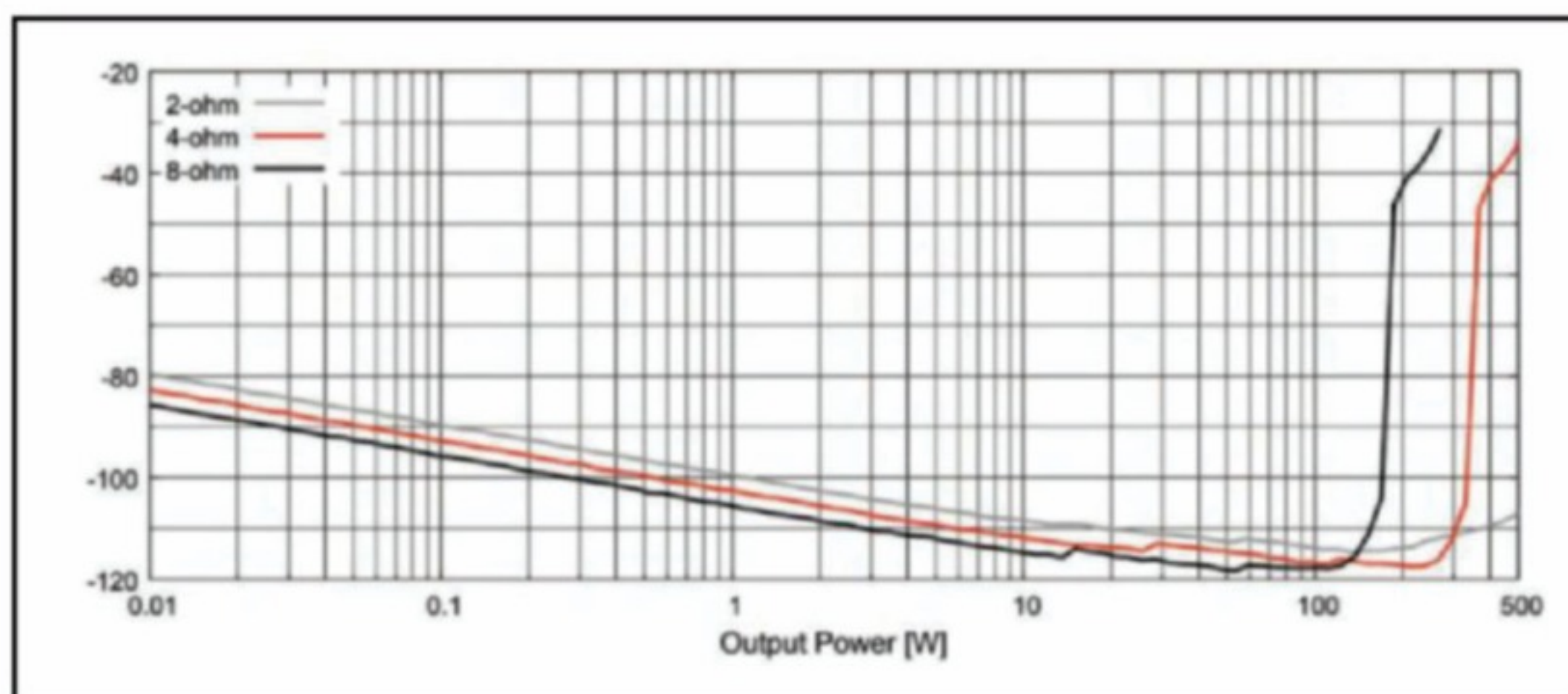


Figure 5: THD+N versus output power shows very low distortion at very high output powers.



Photo 2: Lars Risbo is another of Purifi Audio's founders present at the presentation. (Photo courtesy of Bert Kraaijpoil, AES Netherlands)

the iron in the assembly. That inductance is at a maximum with the coil at the center position. Modern drivers often use some kind of shorting ring, often from copper, to reduce the inductance variation but this setup has the minimum inductance at the maximum coil excursion, so here is an inherent nonlinear system (see **Figure 6**).

That nonlinear force is separate from the desired linear force that's created when the magnet is added to the system. With the cause of the nonlinearity identified, things were in place to develop a cure. With the new motor, they were able to lower the distortion by nearly 40 dB compared to the industry

standard. This is illustrated by the current harmonic distortion graphs (both vs level and frequency). The telltale sign is the HD3 ratio that rises only slowly with level and a HD3 that takes over at higher frequencies after the motional distortion has dropped off (see **Figures 7–9**).

A second issue that limits driver linearity was mentioned as well, namely the effect of the surround. Most surrounds are (a variation on) the half-cylinder. It is easy to see that when the cone moves forward and backward, the equivalent area of the surround that contributes to the acoustic output changes. So this causes a position dependent variation of the

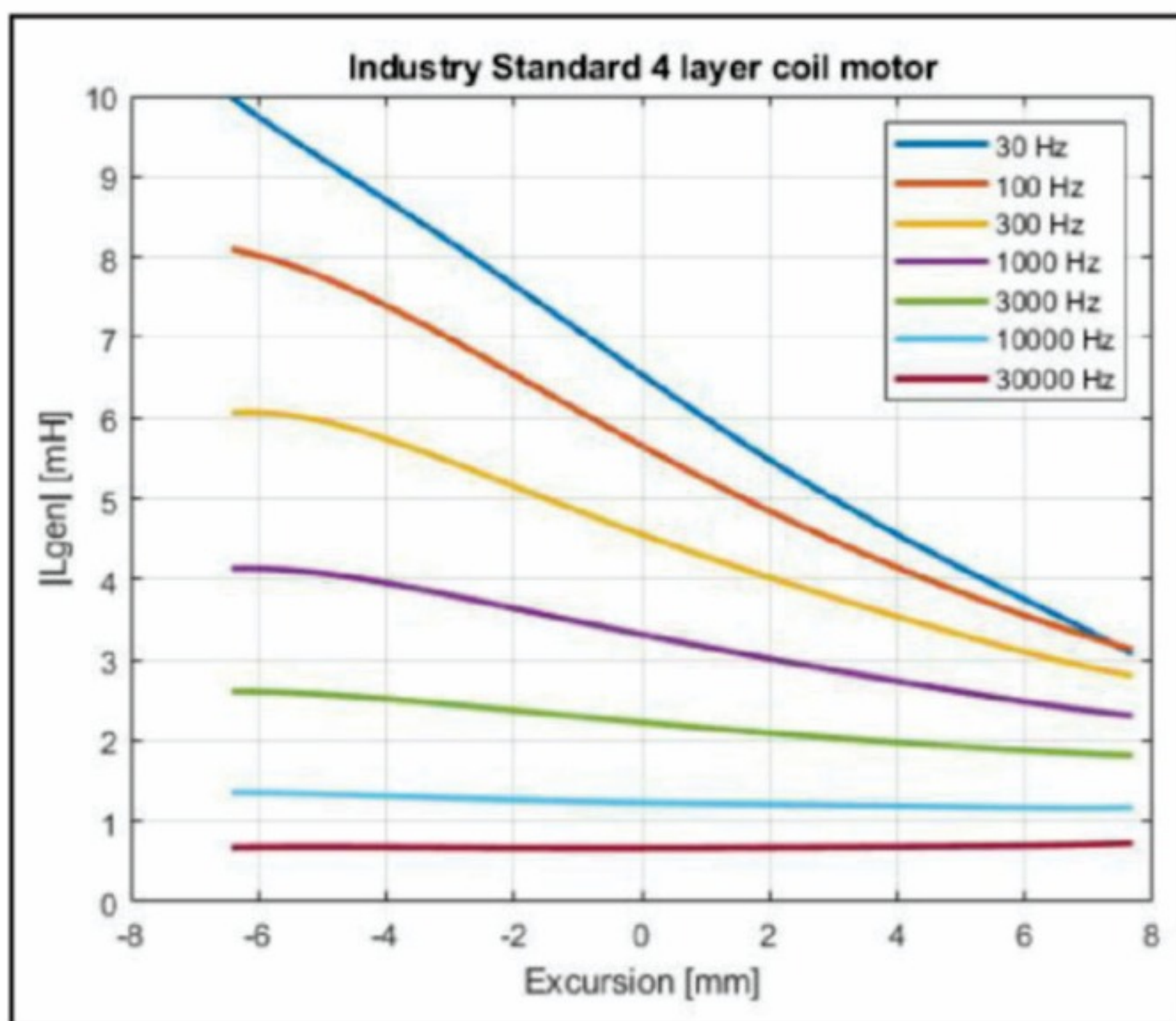


Figure 6: Common industry standard construction shows large inductance variation with frequency and excursion.

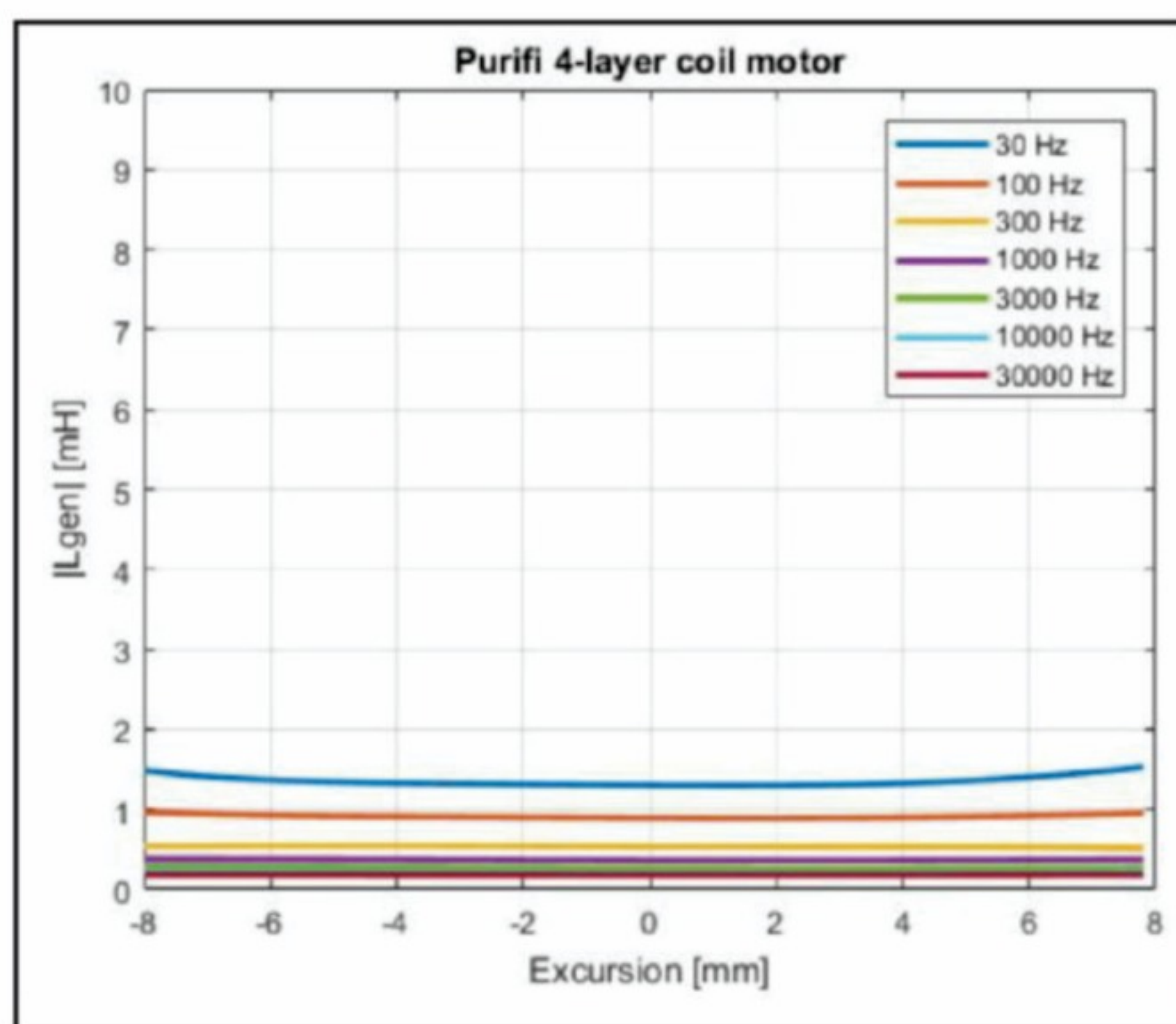


Figure 7: The new Purifi motor shows almost no of inductance variation with excursion and very small with frequency.

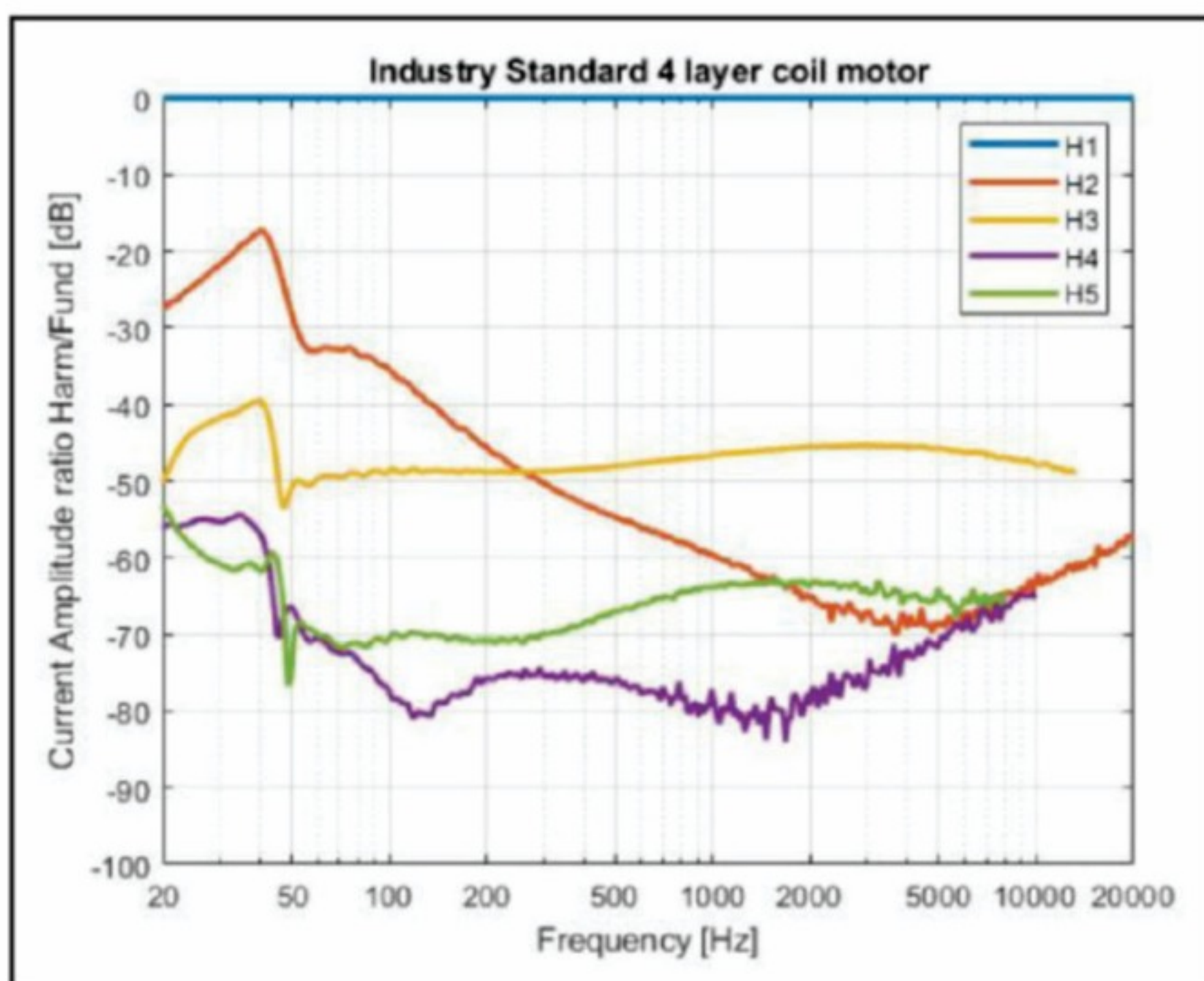


Figure 8: Voice coil current distortion is shown in an industry-standard driver.

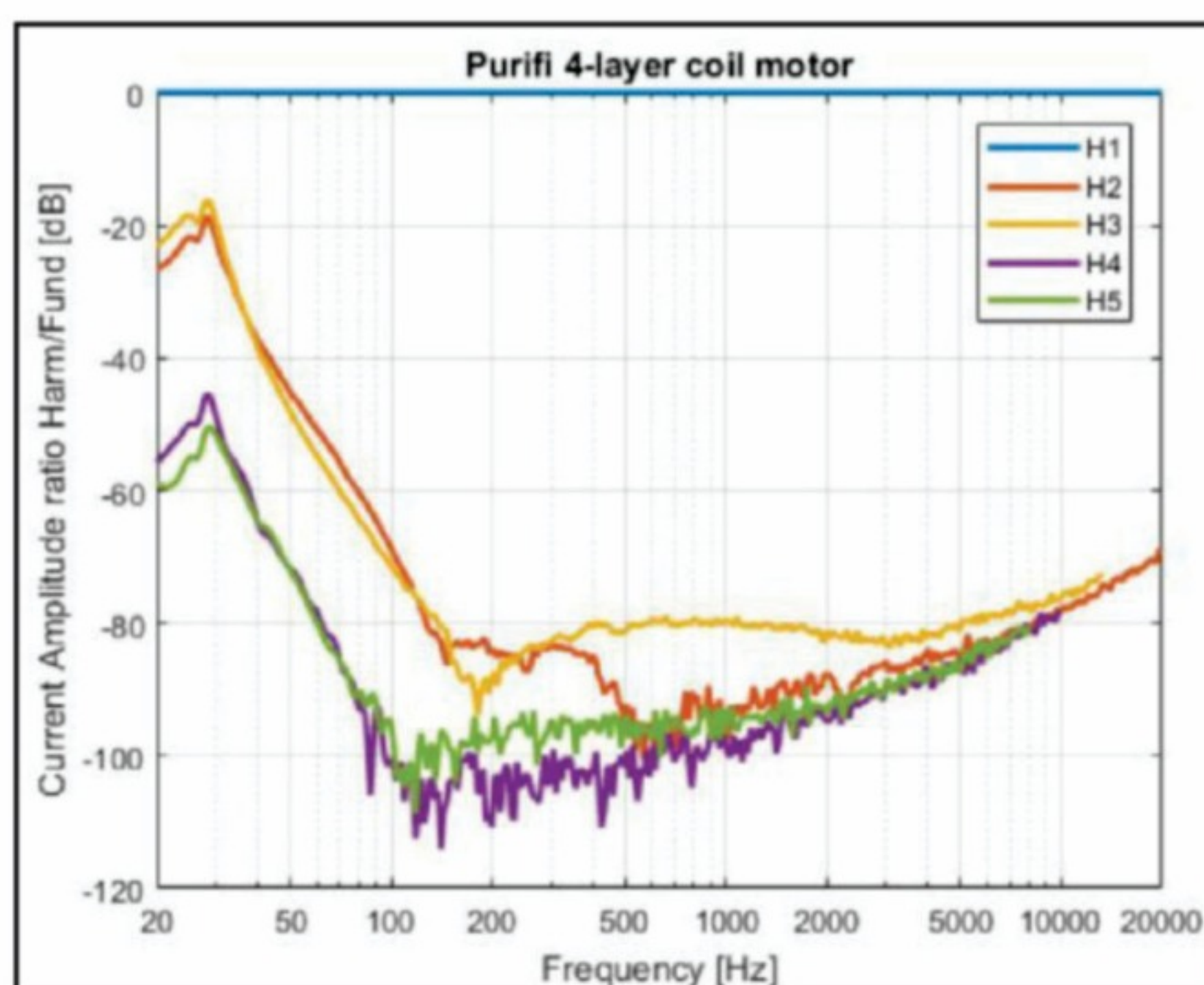


Figure 9: In the new motor, harmonic distortion in voice coil current is very significantly reduced, both versus frequency and versus excursion.

effective piston area which again is a nonlinearity in the system. Some drivers with an experimental surround, designed to keep the effective area constant, were shown and demonstrated in a two-way system. **Photo 3** shows an example of an experimental surround.

This was a very interesting evening with a unique insight in where the thinking about these issues is heading. The performance of our audio systems is higher than it has even been, and because of thinkers like Putzeys and Risbo it still gets better!

For more information about Purifi Audio, J. Martins has included an abbreviated interview he conducted with some of the company's principals. 



Photo 3: The new surround decreases the change of effective radiated surface with excursion, further decreasing the driver distortion.

About the Author

Jan Didden has written for *audioXpress* since the 1970s. He is retired following a career with the Netherlands Air Force and NATO. He worked in logistics, air defense, and information technology. Retirement has provided him with the time to finish all the audio projects that have piled up for decades. He writes about them on his website linearaudio.nl. Jan is also the publisher and managing editor of the twice-yearly bookzine *Linear Audio*.

Resources

J. Martins, "Purifi Audio, Taking It Further," *audioXpress*, July 2019.

J. Martins, "Purifi Audio: A Conversation About Amplifiers and Speakers," June 2019, www.audioxpress.com/article/purifi-audio-a-conversation-about-amplifiers-and-speakers

E. S. Olsen and K. Thorborg, "Diaphragm area and mass nonlinearities of cone loudspeakers," Audio Engineering Society (AES) Convention Paper 4082, AES Convention 99, 1995.

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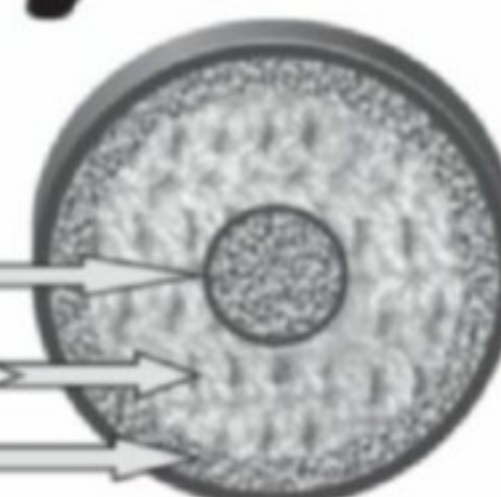
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By
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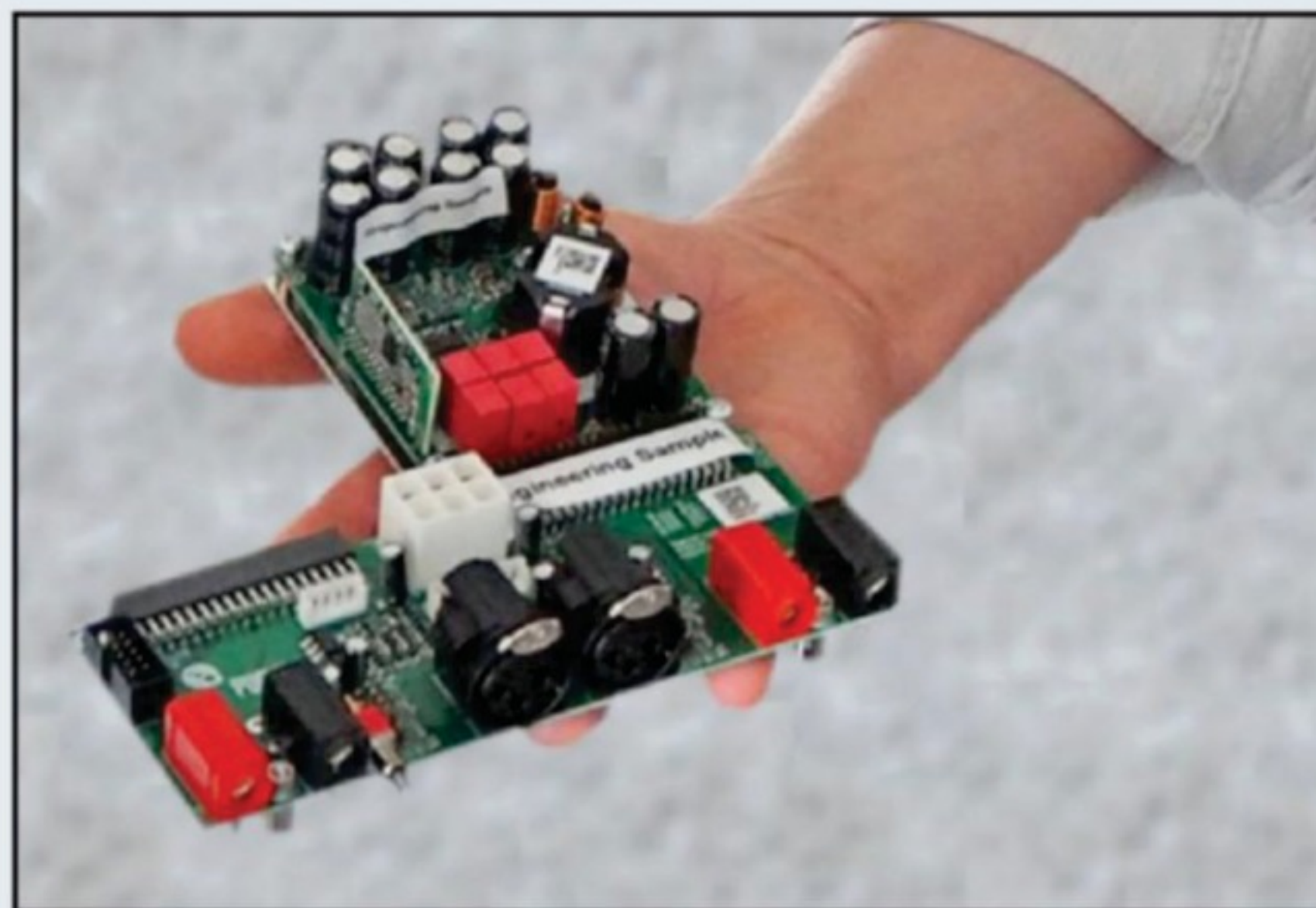
(Editor-in-Chief)

The new Danish audio company, Purifi Audio, was founded by Bruno Putzeys, Lars Risbo, and Peter Lyngdorf, born out of the research work of Class-D pioneers Bruno Putzeys (of Philips, Hypex NCore and Kii Audio fame) and Lars Risbo, who pioneered direct switching PCM-PWM audio amplifiers as founder of Toccata Technology, later acquired by Texas Instruments (TI). With these two founders, we also find the names of Claus Neesgaard, Søren Poulsen, and Kim Madsen, all coming from TI and holding multiple audio patents in the domain. More specifically on the loudspeaker side of the research we can find another co-owner, Carsten Tinggaard, the founder of PointSource Acoustics (2009), the most reputed Danish loudspeaker lab and prototype facilities, and a leading research company in motor design simulation and loudspeaker measurements. Carsten Tinggaard was previously the product manager for Danish Sound Technology (2003) and CTO of Tymphany Denmark (2005). Also now at Purifi is Morten Halvorsen, a Senior Acoustic Engineer at PointSource Acoustics. He co-developed both the loudspeakers and sound unit of the Montana by PointSource products and specialized in electromagnetic simulations, measurements, and procedure optimization. Halvorsen researched force factor modulation, and was responsible for much of the measurement equipment and simulation models developed at PointSource, which Purifi Audio is now expanding.

audioXpress had the privilege to meet and interview some of the Purifi Audio principals just before the opening of another edition of the High End show in Munich, Germany, where the team was making its first public presentation to the industry. During that conversation, we discussed Purifi's projects on loudspeaker drivers and audio power amplifiers and asked questions about their business strategy. The complete interview is now on the *audioXpress* website (see Resources).

But there's an angle that we think we should highlight here. When you read about Purifi's research and you see the measurements, you understand that this research is looking at things differently, because, as Putzeys and Tinggaard, explain, they even had to develop their own measurement solutions. "We would like to tell everybody how we measure and why we measure, the detail of analyzing both harmonic differential tones and multitudes, complex signals, and find where it hurts... But for that, we also needed a new analyzer..." Tinggaard explains.

And Risbo details, "When we started looking at motors we found a major distortion source that was flying under



The new Purifi Audio 1ET400A amplifier module. As Bruno Putzeys explains, the team pursued different routes in amplification "until we bumped into clear mathematical proof that a simple self-oscillating amplifier is a better way of going about it. I always thought that NCore would be my last amplifier of that sort..."



Carsten Tinggaard proudly shows the team's first ultra-low distortion 6.5" long-stroke woofer, which is able to perform in a very controlled manner in the low end, without losing the details in the mid band.

the radar. And it's not captured by the conventional graphs. We can have all these symmetrical plots and as part of that you can have loads of signal distortion. So there was obviously something that's not covered."

As Putzeys expands. "In this specific case, the important information that you need to extract from the motor measurements is the inductance at all frequencies and all positions. And then suddenly you can discover a lot. That's something that we never see being done. Eventually we will see some sort of inductance at a certain position at an unknown frequency, and that doesn't actually tells us what the speaker will do when it sees a signal with one or two frequencies or whatever. So we've built our own analyzer for that and what we care is of course about the data that we needed to understand the problem. Many people will be gutted to ear that we are not going to sell the analyzer... "Essentially, you mount the driver in a fixture like you would do with a Klippel analyzer and then you measure for two seconds and out pops all the data that a Klippel analyzer produces, plus the bit of data that we want."

Neesgaard details further: "...in order to have that level of understanding and dig into the deepest corners, we needed to build our own machine... It's very far from the traditional trial and error. A lot of people talk about simulation, but simulation is also trial and error. This is way more about understanding the problems before you even try to do anything about it."

"We go so far as to prove that the model was actually working, then we build the machine that actually could take the voice coil and move it against the magnet system, get all the data out, as a function of the position, frequency, and then we compare with our analyzer. That has been a constant. So when we have a question, we build, we measure, we compare, to see if there's something that is not matching, and the question will be there until we have solved it and the simulation is verified. So it is a kind of an adaptive signal processing where we are constantly in a loop, between simulation modeling, building, measuring, and listening, back and forth. "Another strong thing that we have is that we can now take out all the different distortion components, because that's what we focused on. Getting the distortion down. Removing all the distortion components. In the driver - where you have the complexity of the electromagnetic, mechanical movements, acoustic radiation, and again not knowing what comes from where - by putting it into a very sophisticated, not only static, but dynamic model, in just two-seconds of measurements, we can decompose all the distortion components and we can begin to see which one of those is."



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Good Vibrations (Part 2)

The Basic Principles of Unwanted Vibrations



When we play back audio, we only want to hear sound waves created from the electro-mechanical vibrations produced by the loudspeaker. They are the result and intention of the artists. They are the original signals. These are good vibrations. But what happens when there are bad vibrations? In Part 2 of this article, we explore ways to solve these issues using various products that AV RoomService, Ltd., provides when helping clients with their acoustic problems.

Photo 1: RoomDamp2 is applied to the back of the second layer of sheathing to act as a constrained-layer damping compound.

By
Norman Varney
 (AV RoomService, Ltd.)

In the noise control industry, the best place to start is usually at the source of the noise. In our example, we start with the loudspeaker. The biggest contributors to unwanted noise and vibration are the walls, the ceiling, and the floor.

I have been serious about accurate music playback since I was a kid. I have been in the business for decades. I am someone whose hobby is also his living. It is because of my love of music.

My company, AV RoomService, Ltd. offers acoustic design and testing services, as well as several original acoustic products, two of which target the problems discussed in this article.

RoomDamp2

We'll start out with RoomDamp2 constrained-layer damping compound. This product was developed for both noise control and sound quality attributes. As we have discussed, partitions are quite easily set into motion from both structural vibrations as well as the airborne sound waves impinging on them. Partitions

with too much mass (e.g., concrete) keep the low frequencies contained resulting in poor sound quality. Partitions with too little mass do not reinforce the low frequencies, which also results in poor sound quality. The partitions must be carefully designed in order to balance the two, while also being airtight for noise control. This requires resilient designs so that the shell is sealed, yet can move and act as a low-frequency absorber.

RoomDamp2 is a viscoelastic paste that remains pliable and never hardens. It has the viscosity of toothpaste and is available in five-gallon buckets. It is applied with a paint roller and is sandwiched between layers of sheathing of OSB, drywall, plywood, etc. (see **Photo 1**).

We have already discussed the fact that the room boundaries contribute a large amount of unwanted vibrations back into the listening environment. RoomDamp2 mitigates sound transmission and improves sound quality. It does this by reducing the movement of the sheathing. When sound energy

strikes the surface of a partition assembly, energy is transferred into the surface sheet material in the form of bending waves. Untreated, structural waves propagate sound energy throughout the floor, the ceiling, or the wall assemblies to other rooms. RoomDamp2 utilizes constraint layer damping technology to force bending waves to induce shear-deformation within a thin applied layer of RoomDamp2. It is these cyclic deformations occurring throughout RoomDamp2 that accelerate energy loss through damping in the form of heat dissipation.

Noise Control

RoomDamp2 absorbs structural vibrations to significantly reduce noise transmission between rooms. This is measured in acoustic labs as transmission loss (TL) from 100 Hz to 5,000 Hz, and rated with the sound transmission class (STC) single number designator. Partition assemblies applied with RoomDamp2 reduce noise levels up to an additional 40% compared to untreated wall assemblies. This applies to noise entering and exiting the room. Not only are rooms quieter for living or sleeping, but the full dynamic range of the listening environment is captured.

Sound Quality

RoomDamp2 reduces partition resonances and room reverberation times resulting in a fast, dynamic, articulate sounding room. Untreated room partitions resonate and store sound energy, which is then re-radiated back into the listening space later in time. They also reflect lower frequency sound energy back into the room. For any critical listening environment, these delayed and reemerged sound energies distort the original sound signal making the room sound slow, muddy, and droning.

RoomDamp2 reduces re-radiated sound energy by dissipating and absorbing wave deformations that impinge upon and within the partition. Rooms sound fast and articulate because the partitions are no longer ringing after the original signal event has stopped. Rooms have more low-level resolution because the partitions are no longer masking new original signal events (direct sound waves).

RoomDamp2 Development

We worked with a couple of different chemists to create various new formulas and compare them to existing products. Our objectives were to offer a product that:

- Is superior to the competition in noise control
- Costs less than the competition
- Is easier to apply than the competition

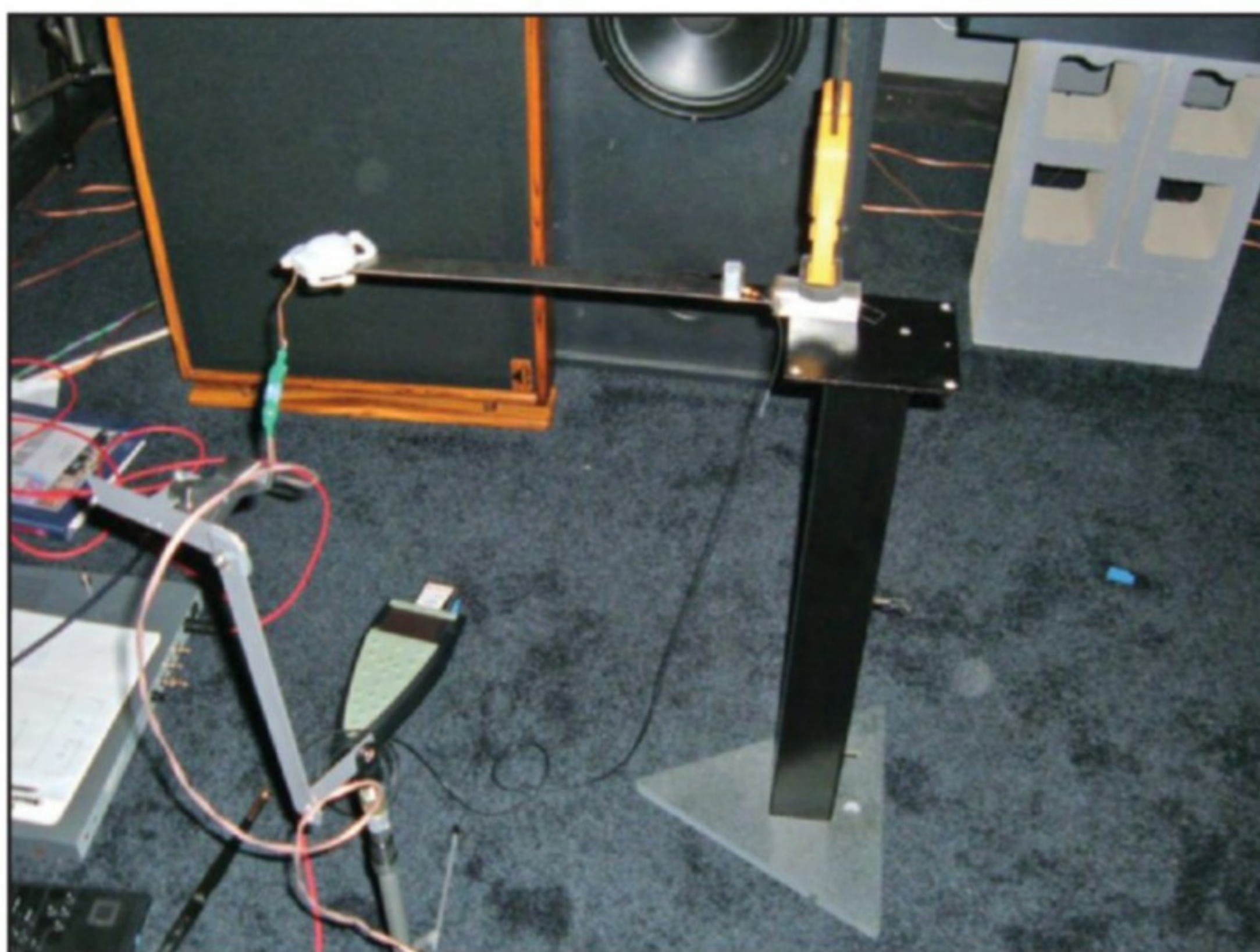


Photo 2: The Oberst bar apparatus with the exciter, an accelerometer, and measurement instruments was used for stage one testing of damping properties of various damping formulas.

- Has less stench than the competition
- Has less waste than the competition
- Cleans up easily
- Is essentially hazardless
- Is made in the USA

As formulas were developed, the testing process went in stages. First, we used an oberst bar apparatus, which measures the dynamic modulus of elasticity, and measures the internal damping factor from 20 Hz to 20 kHz (see **Photo 2**).

If the formula passed this test (see **Figure 1** for the results), we then tested it on a constrained-layer sheathing mock-up. We suspended the mock up with bungee cords, agitated the device under test (DUT) with a piezo exciter, and collected the data with an accelerometer. We positioned the accelerometer

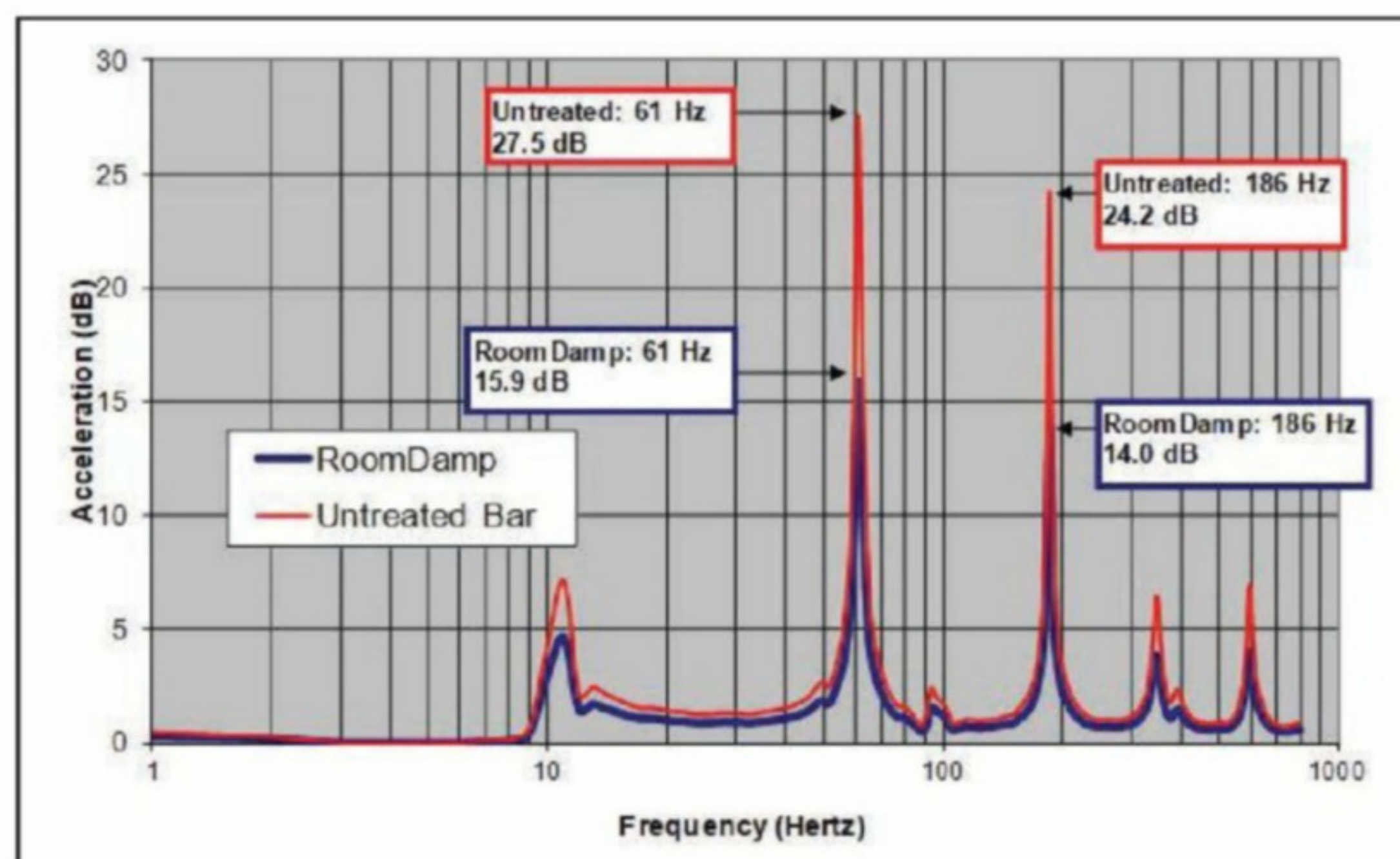


Figure 1: Here are the Oberst bar apparatus test results of an earlier formula of RoomDamp v1. RoomDamp v1 is shown in blue, untreated in red.

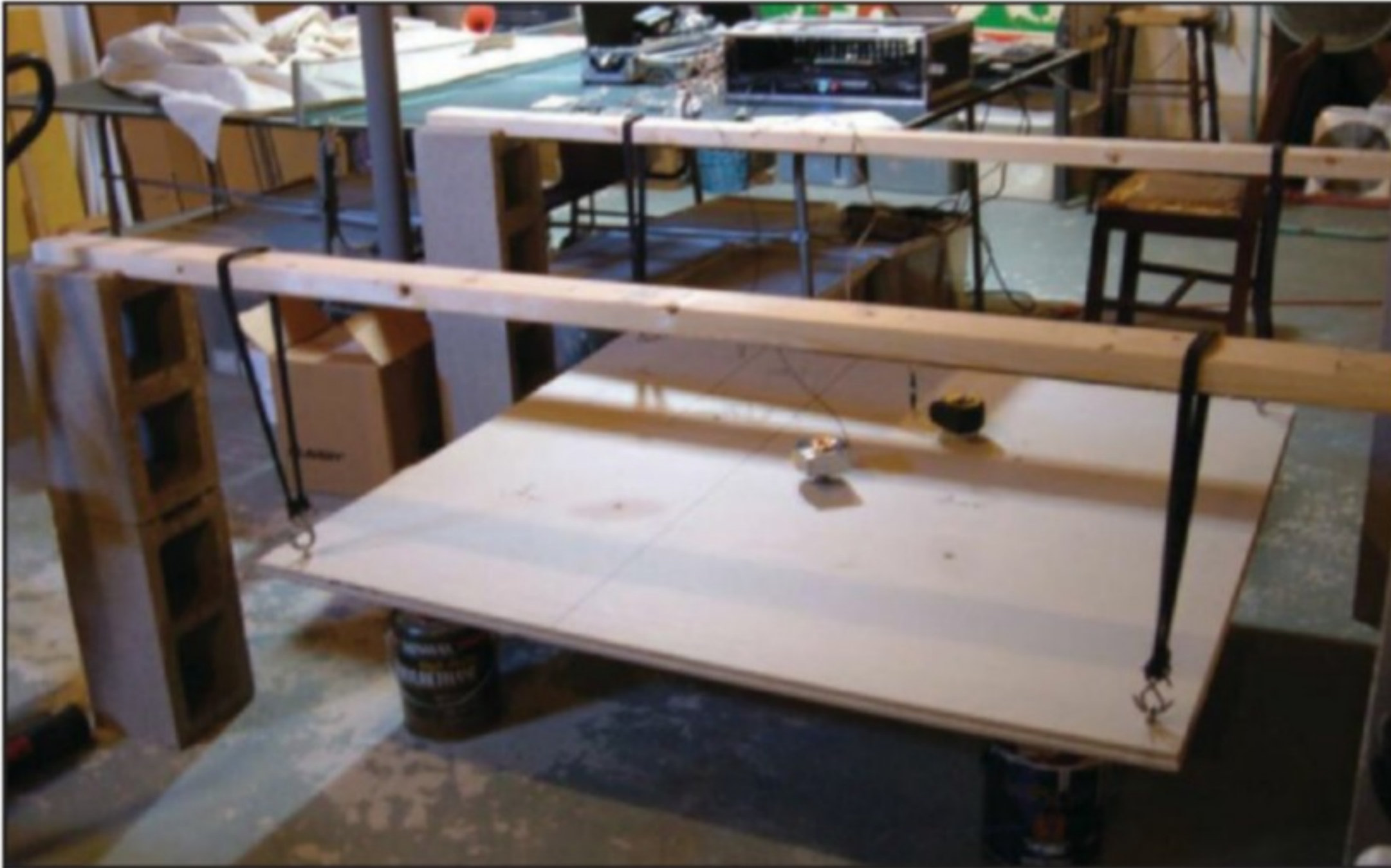


Photo 3: This is a sheathing mock up of constrained-layer damping compound testing. Two layers of sheetrock suspended with bungee cords allow for relatively free movement.

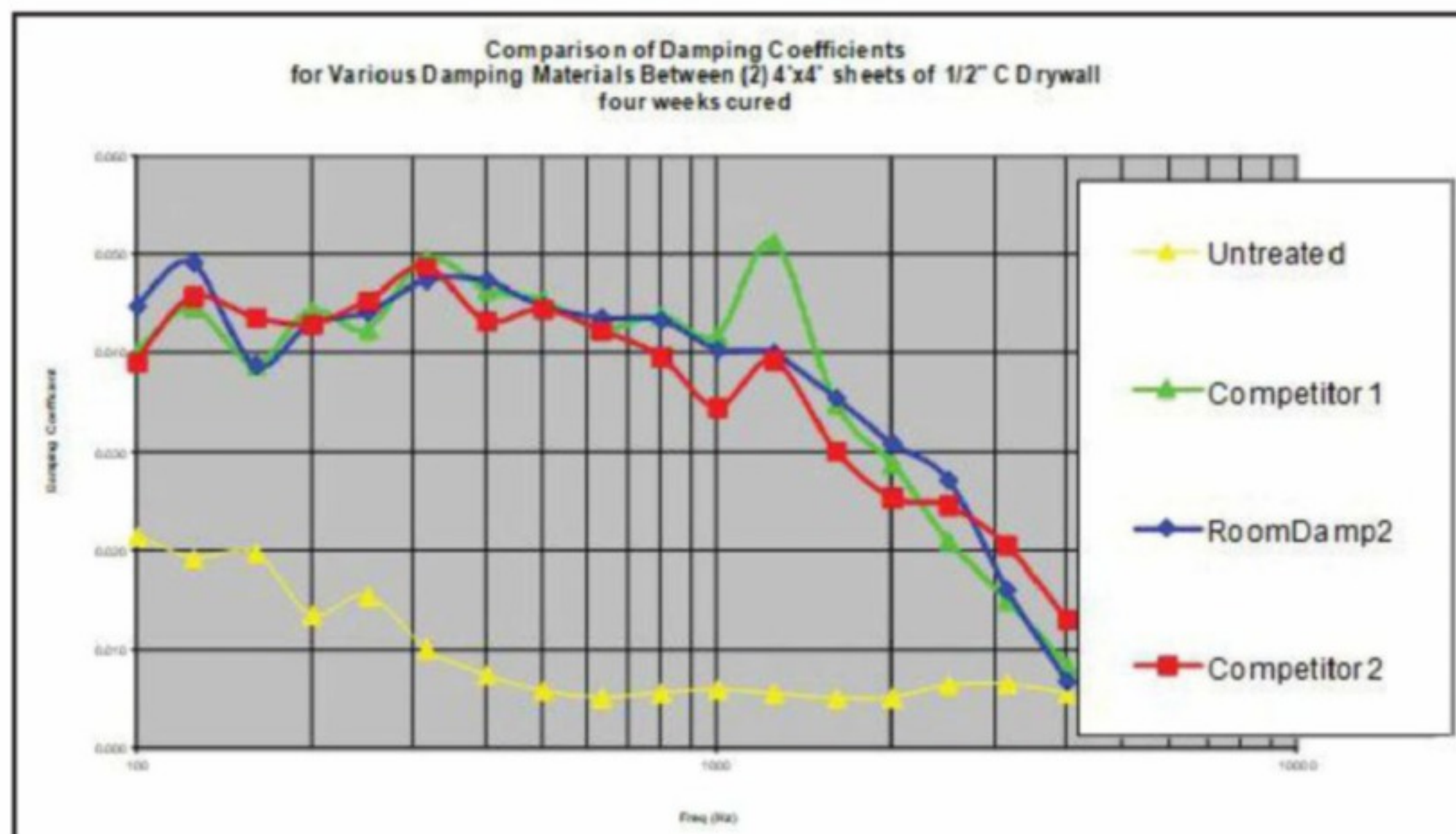


Figure 2: Here is an example of collected data from sheathing mock up tests as seen in Photo 3. We conducted eight formulas. This example compares the best formula to the best two competitors, against no treatment.



Photo 4: The author oversees one of the ASTM E-90 TL tests in the source side reverberation chamber. These are actual wall constructions filling an 8' wide by 12' tall chamber opening between the source and receive reverberation chambers.

around points of a golden ratio drawn on the DUT to control mode interference and averaged the data collected (see **Photo 3**).

If the formula passed this test (see **Figure 2** for the results), we knew we had something worth re-testing at an accredited lab where we would perform an ASTM E-90 Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements. The standard is designed for evaluating the transmission of airborne sound through the test specimen between two reverberation chambers. This involved conducting many tests with several common building wall types and against those of our best competitor.

We tested in a couple of accredited labs with larger reverberation chambers and requested data be collected below the standard frequency limit. The confidence levels were calculated for each of the centered one-third octave bands (see **Photo 4**). We achieved all of our objectives with RoomDamp2 and the E-90 TL results can be seen in **Figure 3**.

EVP Development

The next product we developed addresses the noise source, along with equipment that is sensitive to the influence of vibrations. Our objectives were to make it:

- Applicable to all equipment regardless of price class
- Affordable to most consumers
- Have a natural resonant frequency below 20 Hz
- Available in densities and sizes to accommodate a wide range of loads
- Made in the USA

A vibration isolator is a resilient support, which decouples an object from forced vibration. Natural frequency and damping are the properties that determine the system's transmissibility.

The purpose of vibration isolation for audio equipment is to control unwanted vibrations and resonances from causing adverse effects to both electrical audio signals and sound waves—both airborne and structureborne.

The natural frequency is a function of the stiffness of the isolation system in conjunction with the mass (load) being supported. The purpose of tuned damping is to dissipate the unintended energy as quickly as possible. Transmissibility is the ratio of the output vibration divided by the input vibration. It is the amount of vibration passing through the system. The isolation efficiency of an Equipment Vibration Protector (EVP) is conservatively >80% from about 5 Hz on up. This means that better than 80% of the vibratory force is not transmitted to the support structure or

the equipment.

The EVP core is a matrix of precisely compressed layers of high-density molded glass fibers, which allows controlled air movement through the fibers (see **Photo 5**). This action provides viscous damping, reducing physical motion, while widening the frequency

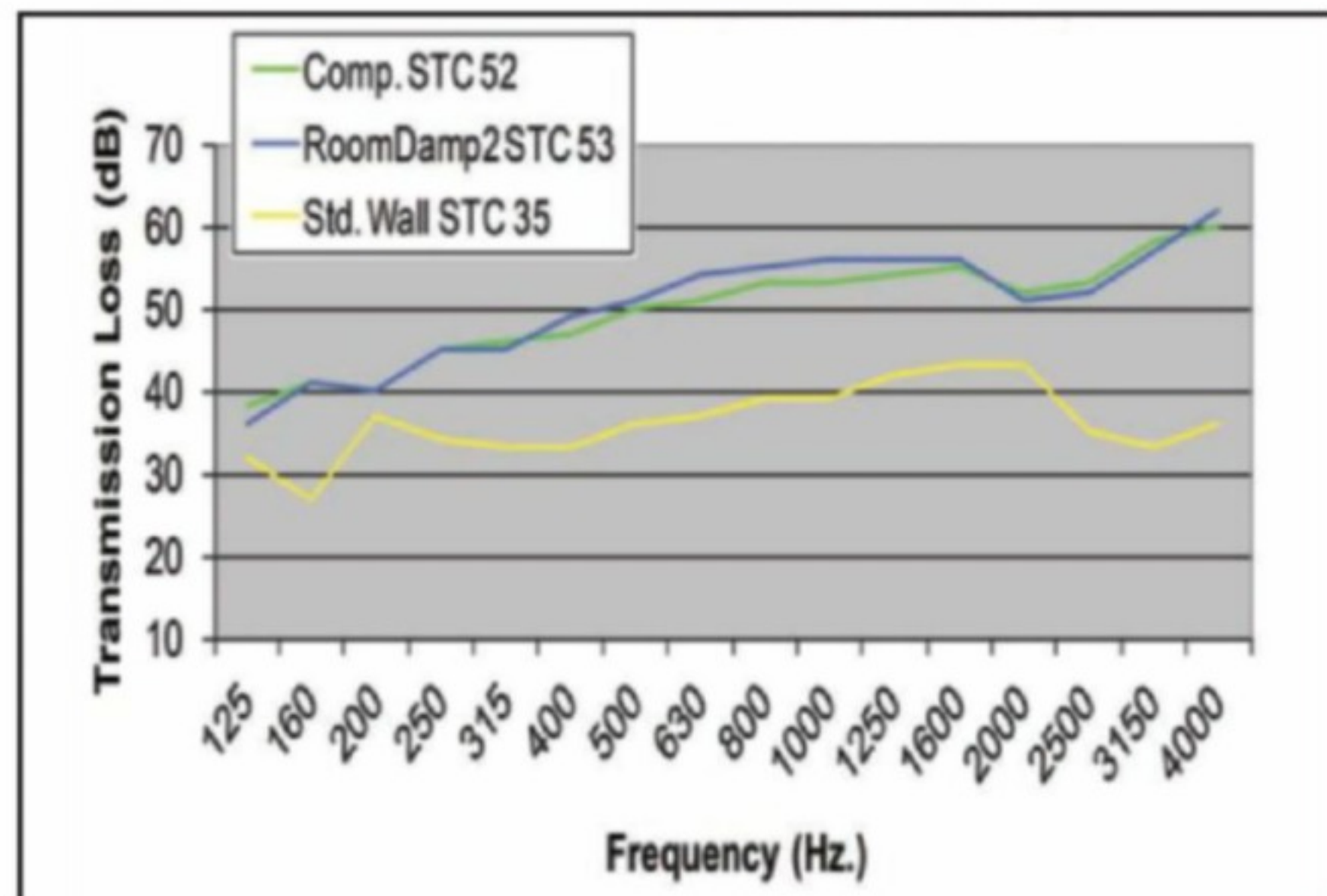


Figure 3: Here are the ASTM E-90 transmission loss test results of a 2' x 4' wood construction with a double layer of 5/8" drywall on the receive side, and a pre-laminated layer of RoomDamp2 on the source side. R-13 fiber glass insulation fill.



Photo 5: Equipment Vibration Protectors (EVPs) are available in 2" and 4" squares by approximately 1" tall, with felt and rubber finishes, and in three standard densities to handle equipment loads from 3 lbs to more than 300 lbs.

About the Author

Norman Varney is the owner of AV RoomService, an acoustic design company that also offers a few acoustical products. Having been in the noise control and sound quality industries for decades, he has earned awards for acoustical products and room designs while working for AV RoomService, Kinetics Noise Control, Owens Corning Science & Technology Center, and MIT. Norman has presented white papers to the industry and written articles on acoustics for numerous publications over the years, as well as participated in seminars and panel discussions. He is an active member of ASTM (Committee E-33 on Building and Environmental Acoustics), the Acoustic Society of America, the Institute of Noise Control Engineering, the Audio Engineering Society, the National Association of Music Merchants, CEDIA, and others.

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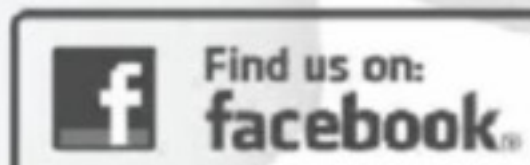
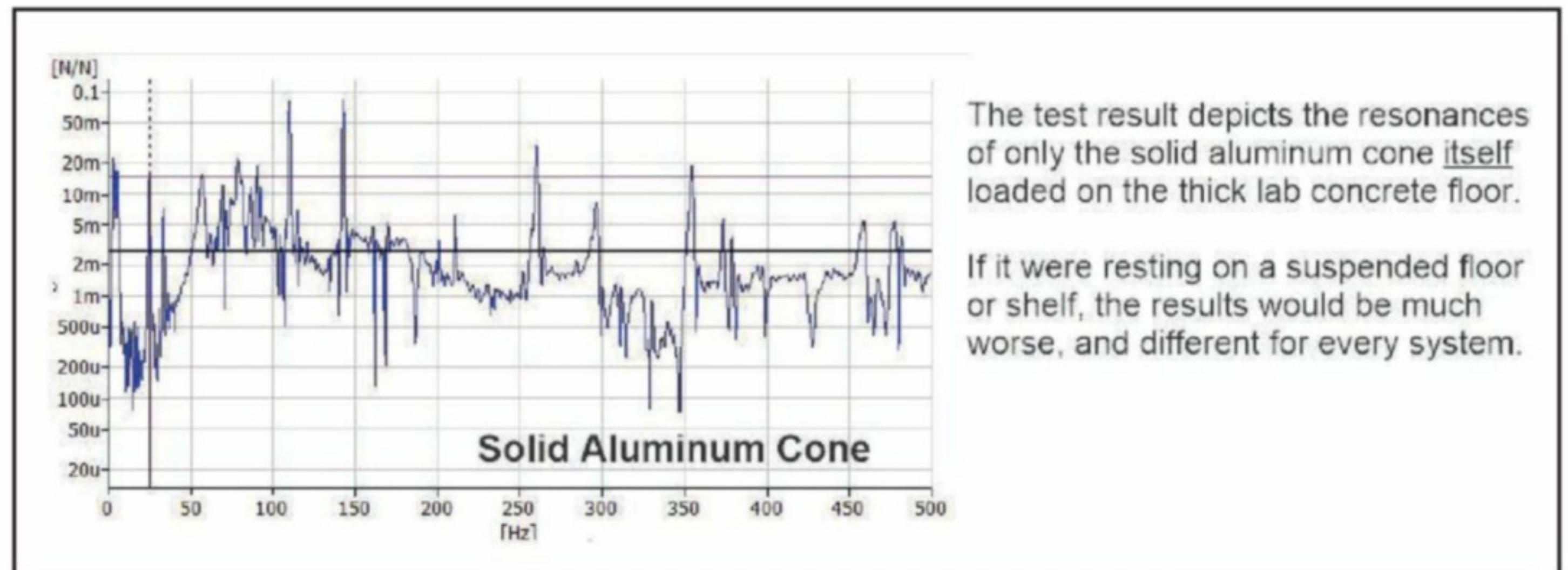


Figure 4: Note that the size, shape, density, and load (not to mention resting platform properties) will act as a filter attenuating some frequencies, while amplifying others.



bandwidth of attenuation. As sound energy moves fibers against fibers, the friction transfers sound energy to heat energy. The annealed fiberglass is produced by a multiple flame attenuation process, which generates fibers having modulus of elasticity of 10.5 million PSI (738,223 kg/cm²) and nominal fiber diameters of less than 0.00027" (6.8 microns).

The matrix of the glass leaf springs is bonded at all fiber intersections with a low VOC water-resistant binder during the molding process under controlled heat and pressure. The material is then stabilized by multiple pre-compression cycles to many times the maximum published load capacity for the specific density of the media.

The cold-rolled steel plates on the top and bottom of the pad function to evenly deflect the weight across the whole surface for even weight distribution. They also allow existing cone or spikes to be used without damaging or compromising the performance of the pad.

Our own RoomDamp2 constrained-layer damping compound is used to bond the steel plates to the fiberglass core. This damping further improves the EVP absorption properties by lowering the Q-factor, which broadens the bandwidth, reduces ringing, etc. RoomDamp2 is a viscoelastic paste that remains pliable and never hardens. The paint applied to the fiberglass pad is a very special formula that allows flexing. This elasticity means the pad can be compressed without the paint cracking or flaking. The formula contains low VOCs and is UV protected. The flexible paint does cause slow shape-return after pad compression. Unlike other elastomeric materials, EVPs are resistant to water, mold, sunlight, humidity, age, and extreme temperatures.

EVP Use

EVPs are vibration isolation feet for high-fidelity playback and recording equipment, as well as guitar, bass and keyboard cabinets, microphone stands, etc. EVPs allow equipment to perform optimally,

quiet the room, and prevent vibrations from being transmitted to adjoining spaces. Structural vibrations and resonances are no longer heard, leaving only the pure original loudspeaker signals.

EVPs decouple vibration transmission. They do so by transforming the mechanical energy into thermal energy. Most of the competition offer one-size-fits-all devices, and/or couplers, as in rigid spikes, blocks and cones.

In regard to resilient isolators as in rubber, cork, sorbothane, etc., it should be well understood that in order to perform properly (mitigate vibrations in the audible range) the device must have a natural resonant frequency below 20 Hz. under the load designed. Most do not and most have no test data published to back their claims. Understand also that if the device is loaded with too much or too little weight, it cannot perform as designed.

In regards to couplers (hard spikes, cones and blocks), there are a couple of misconceptions:

"Because there is so little surface contact area, very little vibration can be transferred." Though true when applied to resilient materials, it is not true with solid materials. It actually acts as a very efficient conduit for vibration transfer. In some situations, the heavier the load, the better the transmission. Note that the size, shape, density, and load (not to mention resting platform properties) will act as a filter attenuating some frequencies, while amplifying others (see **Figure 4**). The audible results can be for better or worse, never predictable or neutral.

"The small contact point acts as a vibration sink or ground." This too is false. We already know that the vibrations will be efficiently transmitted to the resting platform, which will then likely continue to be transmitted throughout the connected structure. Vibrations can also be transmitted to the source, which in fact, this can also alter the sound.

This is a good place to talk more about sound energy characteristics in dense materials. Of course, every material has a density and that density affects

sound energy in two particular ways of interest to our listening environment:

- The speed of sound travel increases with density. In air, it travels about 1,130 feet per second or 343 m/s. In rubber sound travels approximately 60 m/s, in glass 4,650 m/s, in steel 5,960 m/s. Hence, you can hear the train coming with your ear on the rail well before any other indicator.
- The distance of sound travel increases with density. Hence, whales can communicate with each other hundreds of miles apart in salt water.

Noise Control

By reducing sound transmission to adjacent spaces, other occupants are not annoyed because vibrations are not transferred into the building structure. EVPs have been lab tested and found to conservatively eliminate vibrations to and from equipment from about 5 Hz and up, by >80%. This is done by converting the mechanical energy into thermal energy. The result is audible from both a sound quality and a noise control point of view.

Standard EVPs are 2" or 4" squares by about 1" tall (approximately 51 or 102 square x 30 mm tall). Standard EVPs are black with felt or rubber top and bottom.

Sound Quality

Clarity, dynamics, timbre, and soundstage are improved because resonances and vibrations are nearly eliminated. Floors, walls, ceilings, and furnishings cause unwanted resonances and vibrations, which can be re-radiated into the room. Vibrations can even cause sonic degradation in electronic components, their connections, errors of laser reading and turntable playback, resulting in data corruption, phase distortions, noise, etc.

Microphony occurs when electrical components receive mechanical energy and convert it into electrical energy, thus distorting the signal. Tubes and phono cartridges are especially susceptible. Crystal oscillators in digital products can be effected by vibrations by changing their frequency slightly, causing timing errors. Turntables are certainly the most sensitive to vibrations, amplifying them over the speakers, sometimes even to the point of feedback. They are also most sensitive to footfalls being picked up and amplified, or causing mistracking.

The first and best place to decouple vibrations is at the source, the loudspeakers. This will prevent structural vibrations, not of course airborne. RoomDamp2 will affect both.

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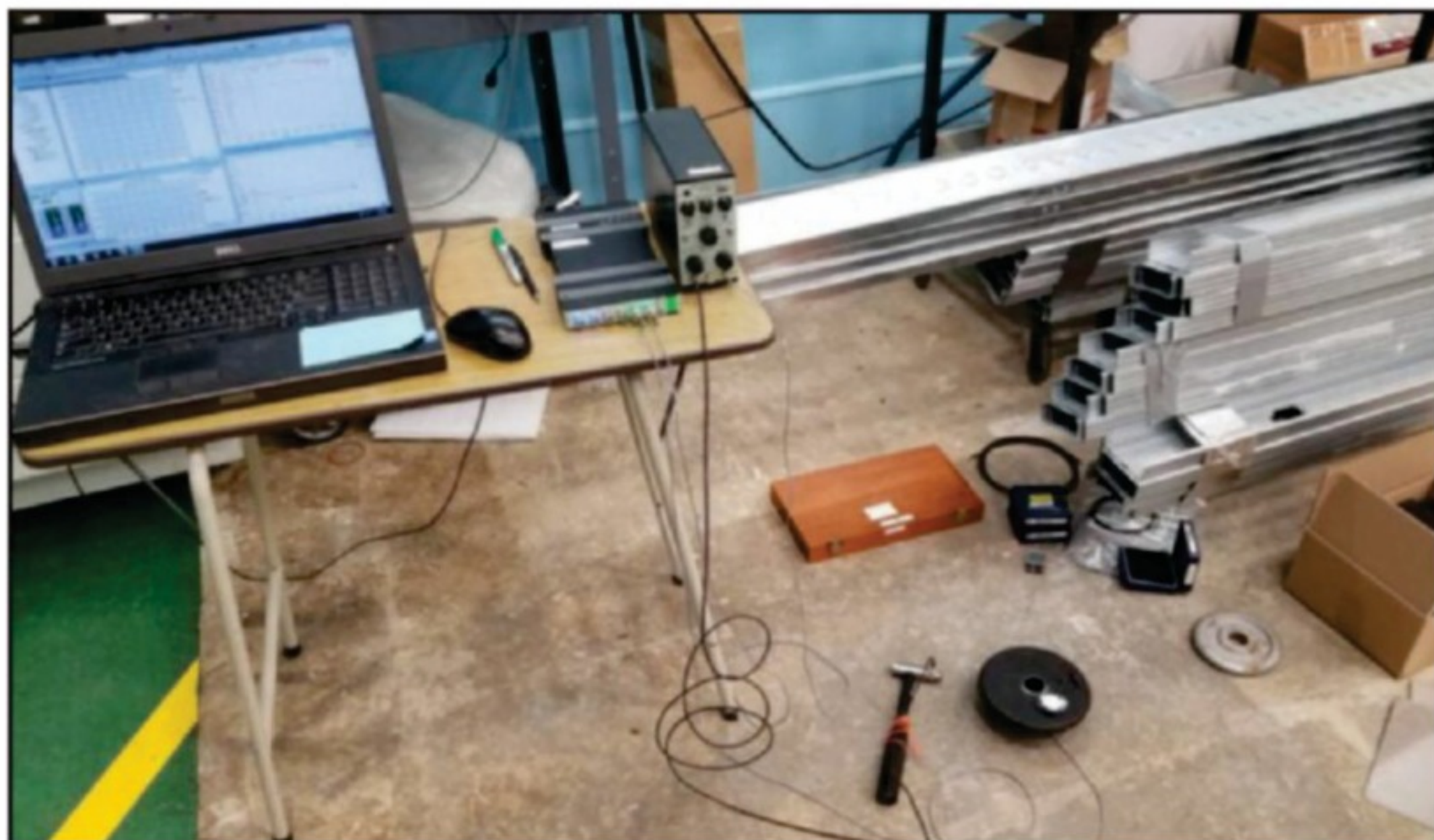


Photo 6: Here are lab test instruments for impulse hammer vibration transmissibility tests of EVPs.

Vibration Transmissibility Tests

The force sensor in the impact hammer in conjunction with the movement sensor of the accelerometer serves to provide a frequency and amplitude measurement of the energy that is

transmitted through the test sample (see **Photo 6**). The system ensures that the structural characteristics of the hammer are filtered out and do not influence the measurement data. The hammer strike is extremely light (about the force of a pencil tapping a desk). A strike that is too hard, too soft, or a double hit is detected and rejected by system parameters. Each test sample was load tested incrementally from below to above its estimated ideal load range. Each test result is an average from five clean tests. Tests indicating poor or questionable coherence results were not collected. Tests were for vertical single degree of freedom movement, and a bandwidth of 1 Hz to 500 Hz. The single degree of freedom set up provides the most basic control system, eliminating the possibility of unique and/or additional material influences. The 500 Hz upper limit was deemed high enough to prove continued isolation, yet low enough to show low-frequency detail, which is of primary interest. Test samples were randomly selected. A sample representing each density, size and finish type was tested through its applicable load range. The vibration energy transferred from the impact, through the isolation sample, is received and recorded by the accelerometer (see **Figure 5**).

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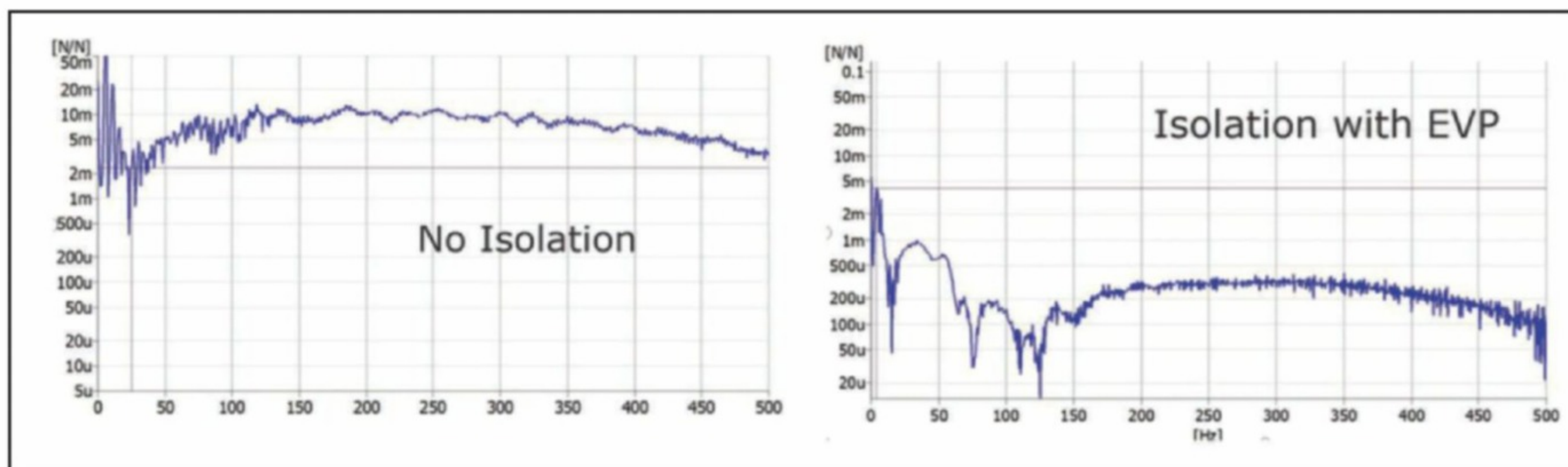


Figure 5: A sample representing each density, size, and finish type was tested through its applicable load range.

Test Conclusions

It should be very apparent from the measurements that solid materials transfer significant energy to whatever they are in contact with. Different solid materials transfer different energies depending on their densities, size, shape, and in conjunction with the characteristics of the material(s) it is resting on. Some frequencies are attenuated, while others are amplified. This coupling is the reason why wood, metals, and even rubber can sound different, but never neutral. In addition, solid materials will deliver a unique response for every system configuration; coupling material, resting platform, equipment weight, etc. The EVPs offer

a predictable, repeatable, reliable solution to decouple and isolate audio equipment from transferring or receiving vibrations.

In Summary

Loudspeaker cabinets vibrate and can transfer their vibrations into the structure. The structure can vibrate and radiate new vibrations into the room after the original, direct sound waves have stopped. The partitions will absorb, transmit, reflect and re-radiate sound energy. These unwanted vibrations interfere with the wanted vibrations. Learn more at avroomservice.com/products. 

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Listening to Modeled Amp Designs Using LTspice

Discover how LTspice has changed the way audio designers achieve the sound they want and how it saves time, eliminating the need to solder or desolder components.

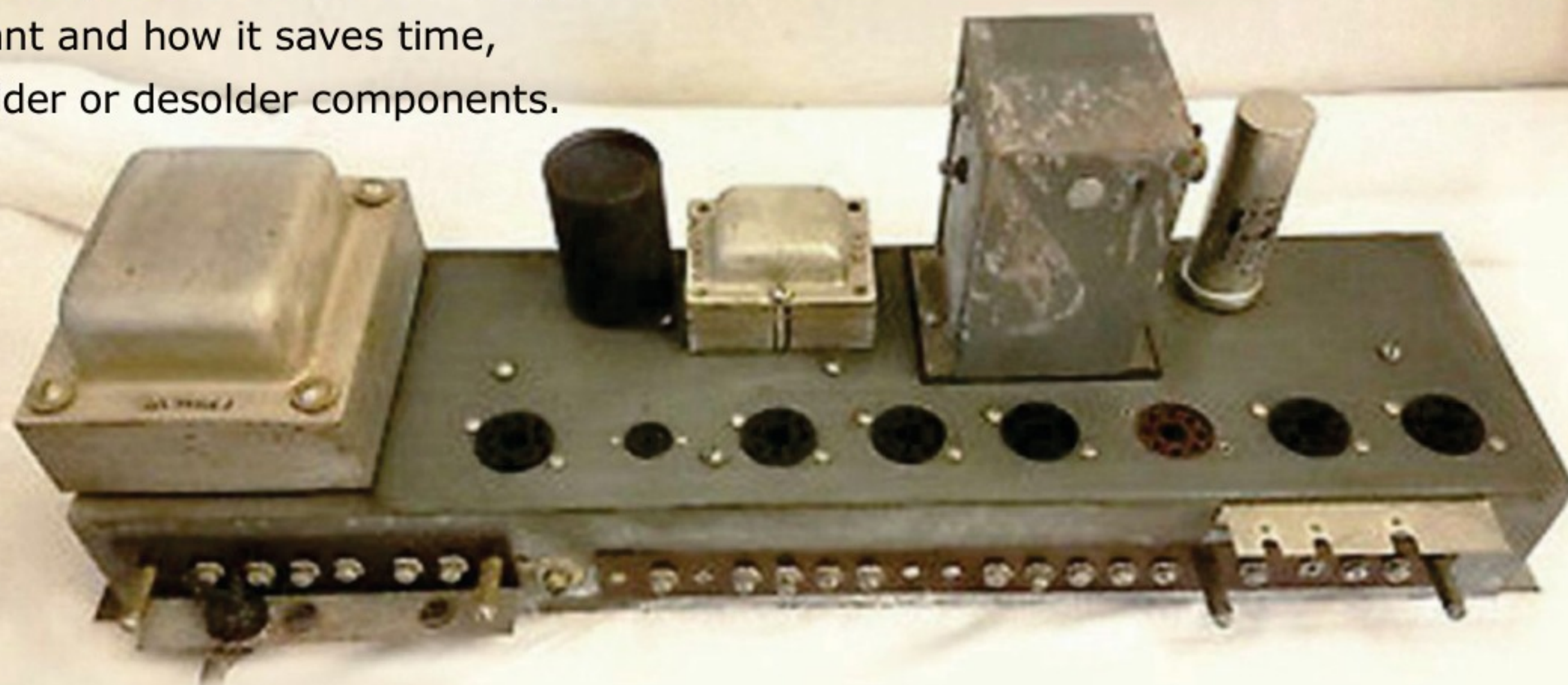


Photo 1: Old Hammond organ amplifier chassis

By
Richard Honeycutt
(United States)

During my years teaching college electronics, I had many memorable students. Of these, two stand out in terms of their love of hollow-state electronics. Both were musicians, and both had experimented extensively with hollow-state musical instrument amplifiers before entering college.

One of the students was the son of a maintenance man, who performed carpentry, plumbing, and electrical repairs for various businesses and organizations. During the 1950s, he taught himself to repair radios and TVs. He passed these skills along to his son, whom we'll call Chad. The other student—whom we'll call Tom—was self-taught. Chad was a fine

keyboardist, a skill he learned from his mother, who was a church organist. However, to the distress of his parents, Chad applied his musical skills to rock music. Tom attended a church in which amplified music was used, and played both guitar and keyboards.

In the 1960s, both Chad and Tom found that they strongly preferred hollow-state guitar and keyboard amplifiers over solid-state ones. But neither was completely happy with the sound of the commercially available amps of the day. So they began modifying amps to suit themselves. After a few years, other musicians heard their amps and began to ask for special modifications on their own equipment. Eventually, Tom targeted his time more toward playing music and building/operating sound systems, while Chad started his own boutique amplifier company.

In designing tube amps or creating modifications for existing ones, both Chad and Tom usually began with an old chassis containing good transformers, filter chokes, and controls, or at least holes for mounting replacement controls (see **Photo 1** and **Photo 2**).

LTspice

While this practice of recycling old chassis saved a lot of mechanical effort—and some money, too—the process of getting the correct sound was still a matter of applying electronic principles, desoldering and soldering components, and listening. Today, we



Photo 2: Fender "Twin" Guitar amplifier chassis

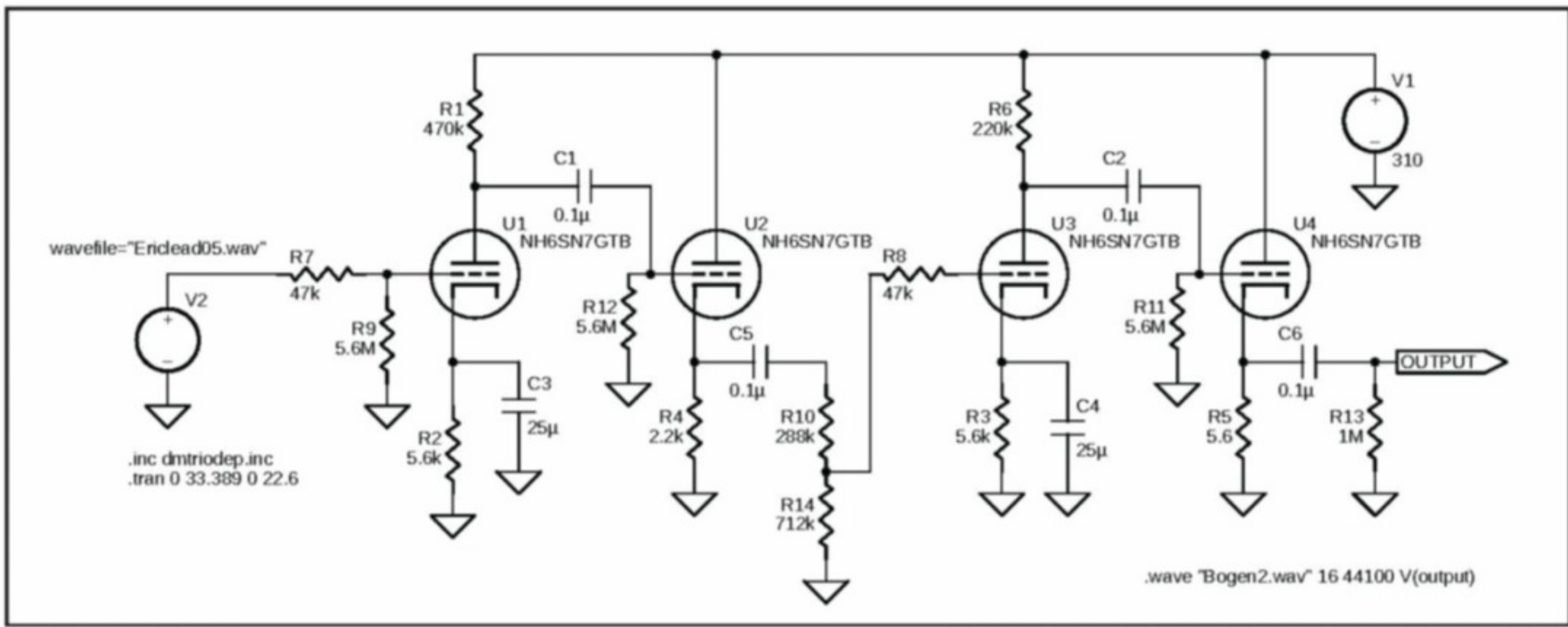


Figure 1: LTspice model of a guitar preamp

have modeling software such as LTspice, which allows us to create our designs on paper and test them with virtual sine waves, examining the output on a computer screen.

The problem is that looking at a waveform is not the same as hearing it. Not only does the translation of a waveform's appearance into an imagined sound require a lot of experience, but the effect of a certain level of distortion upon the sound of a varying-amplitude signal is almost impossible to evaluate from a visual display.

Although Chad and Tom eventually purchased oscilloscopes so they could see the output waveforms of their amplifiers, they still based their engineering and artistic decisions upon what they heard through the speakers.

LTspice has a capability with which many users are not familiar, but which can ease the process of creating and evaluating audio amplifier designs. This is the ability to accept a .wav file as a signal input and to create an output .wav file. By using this process, we can investigate an amplifier's predicted sound with a digitized recording of an actual electric guitar or other instrument fed to the input. Of course, in listening to the output on headphones, we lose the effect that the speakers have on the way the instrument and amplifier would sound live, but we can get a very good idea what the amp's characteristic sound will be like with a certain signal input. If we wanted, we could play the .wav file through a very clean amplifier driving the actual instrument speaker we plan to use, and thus we could hear the amp sound with speaker effects included.



Figure 2: Dialog for labeling output



Figure 4: Dialog for specifying output port



Figure 3: Dialog after selecting "Label Net"

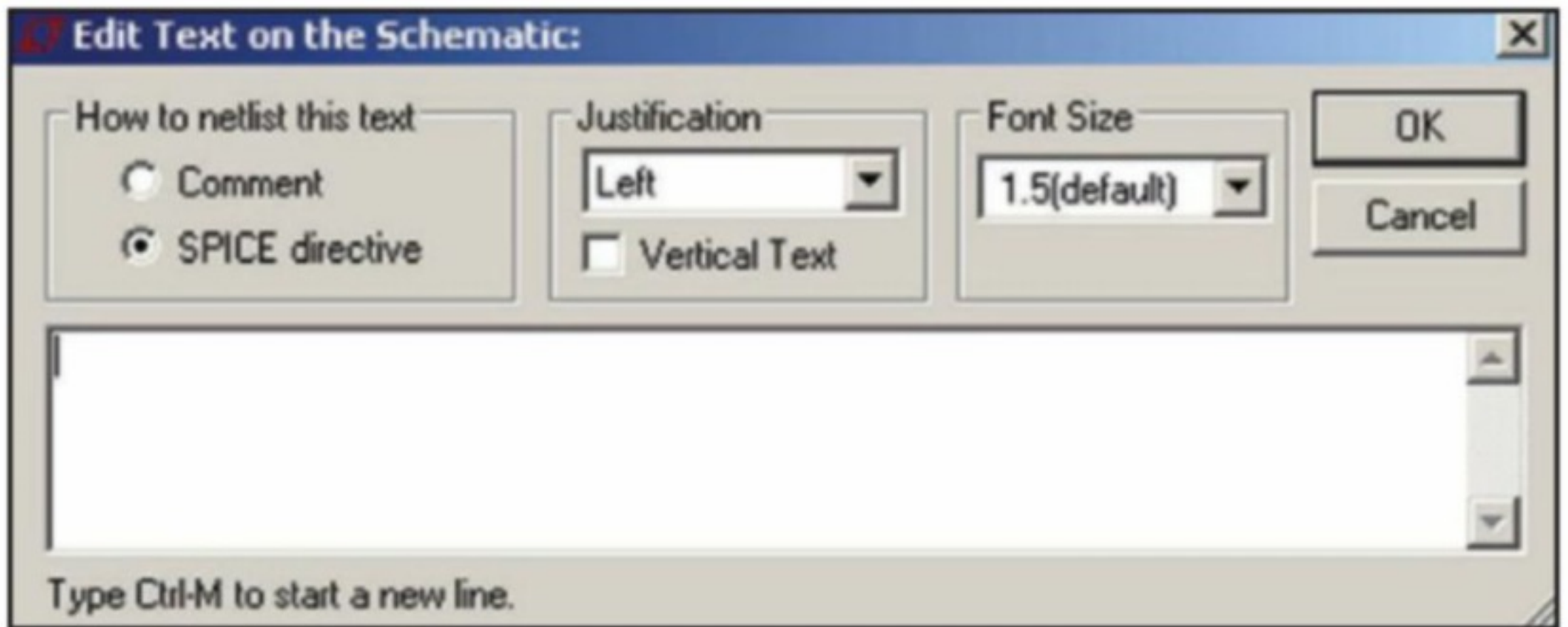


Figure 5: Telling LTspice to write from the OUTPUT Port to a .wav file

Creating LTspice Models for Loudspeakers

David Murphy and Marshall Leach have presented Audio Engineering Society (AES) papers demonstrating how to create LTspice models for loudspeakers. So another way to include the effects of the speaker



Figure 6: Input .wav file



Figure 7: Output .wav file, input 50 mV peak



Figure 8: Output .wav file, input 100 mV peak

in your output .wav file would be to build a model of the speaker into the LTspice model. This sort of modeling is reasonably accurate at low frequencies, but not at high frequencies, where cone breakup is important to the sound of the speaker. So adding the speaker model to your amplifier model is not nearly as accurate a way to include speaker effects as the method discussed above.

Figure 1 shows an LTspice model of a dual-6SN7 guitar preamplifier. In order to use a .wav file as an input, you just enter the filename as the “value” of a voltage source. It’s easiest if the .wav file is saved in the same folder as the LTspice file that you’re working with, but you can also enter the full address of the file (e.g., C:\Users\Richard\Documents\Preamp\guitar.wav). You can use a .wav editor to adjust the input amplitude to the desired voltage. Many .wav editors allow you to read the output voltage in dB, usually dBV, even if the screen does not show the “V”.

Since .wav files are limited to representing instantaneous voltages between -1 V and $+1$ V, the output should be passed through a voltage divider designed to keep the circuit’s output level within this range. The voltage divider can be inserted anywhere in the signal path; for instance, if you want to hear only the distortion produced by the first two stages in the preamp shown in Figure 1, you could put a voltage divider (R10 and R14 in Figure 1) between C5 and R8.

You need to label the output in order to specify the signal to be written to the output .wav file. To label the output, left-click on the circuit node from which the output is taken: the junction of C6 and R13 in Figure 1. You will see the dialog box shown in **Figure 2**. Clicking on “Label Net” will bring up the dialog box in **Figure 3**. You can type in the label for the node (I used “OUTPUT”) and select the type of port from the drop-down box—I selected “Output” (see **Figure 4**). Then when you click “OK”, the symbol for an output port, with the port name inside, appears, and you can drag and drop it as you like.

Next, you tell LTspice to write the output to a .wav file. Click on Edit in the bar at the top of the screen, and select “SPICE Directive”. The dialog box shown in **Figure 5** will appear. I typed “wave Bogen2.wav 16 44100 V(output)” into the text block, specifying the .wav file name, 16-bit resolution, 44,100 sampling rate, and the voltage at the output port as the signal. Of course, you could use the full address for the output .wav file if you didn’t want it to be written in the default folder for the LTspice project.

The input .wav file was created using Adobe Audition software with the guitar (Gibson Les Paul) fed directly to the M-Audio M-Track USB sound adapter, and levels adjusted so that no clipping

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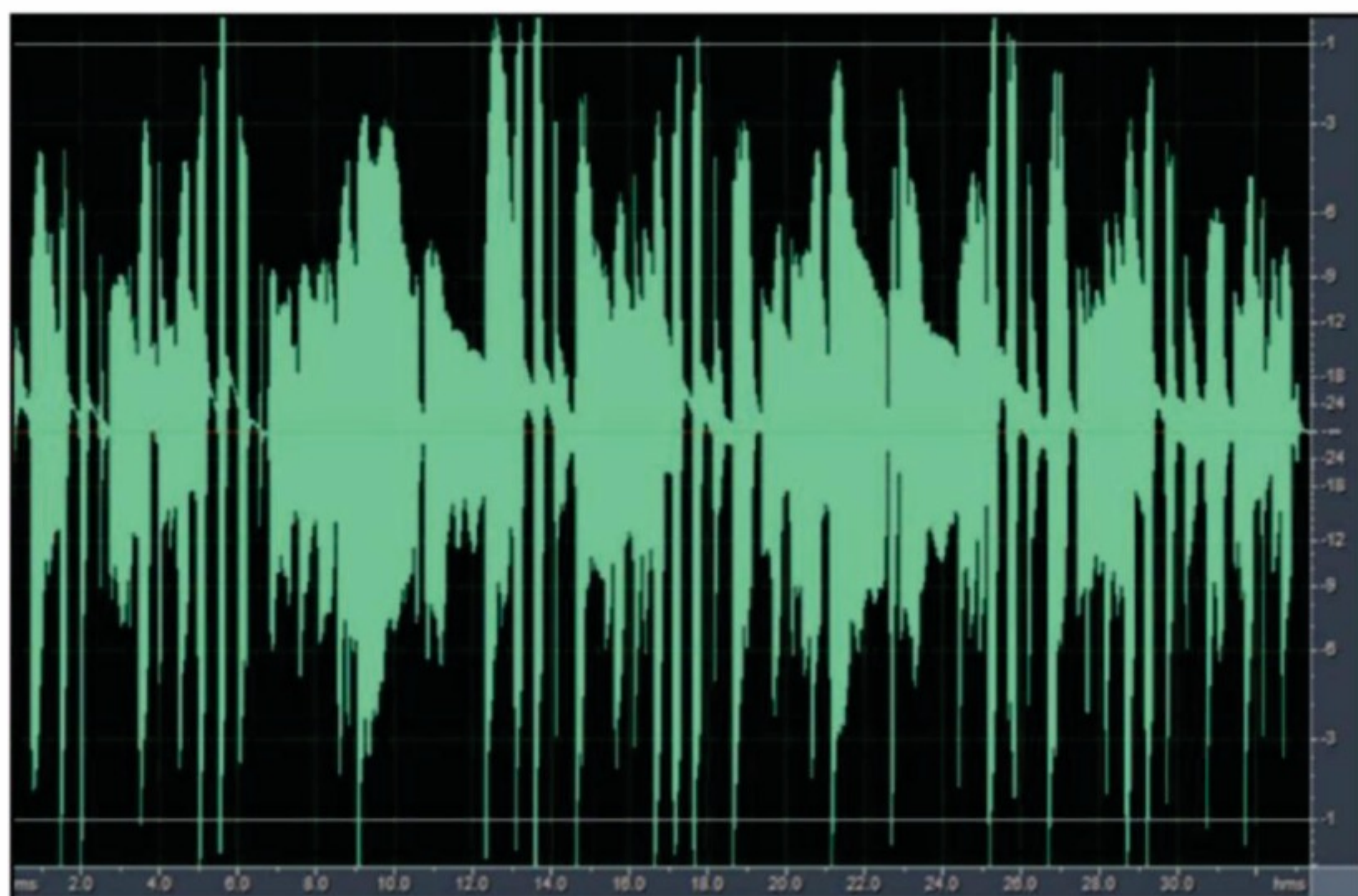


Figure 9: Output .wav file, input 150 mV peak

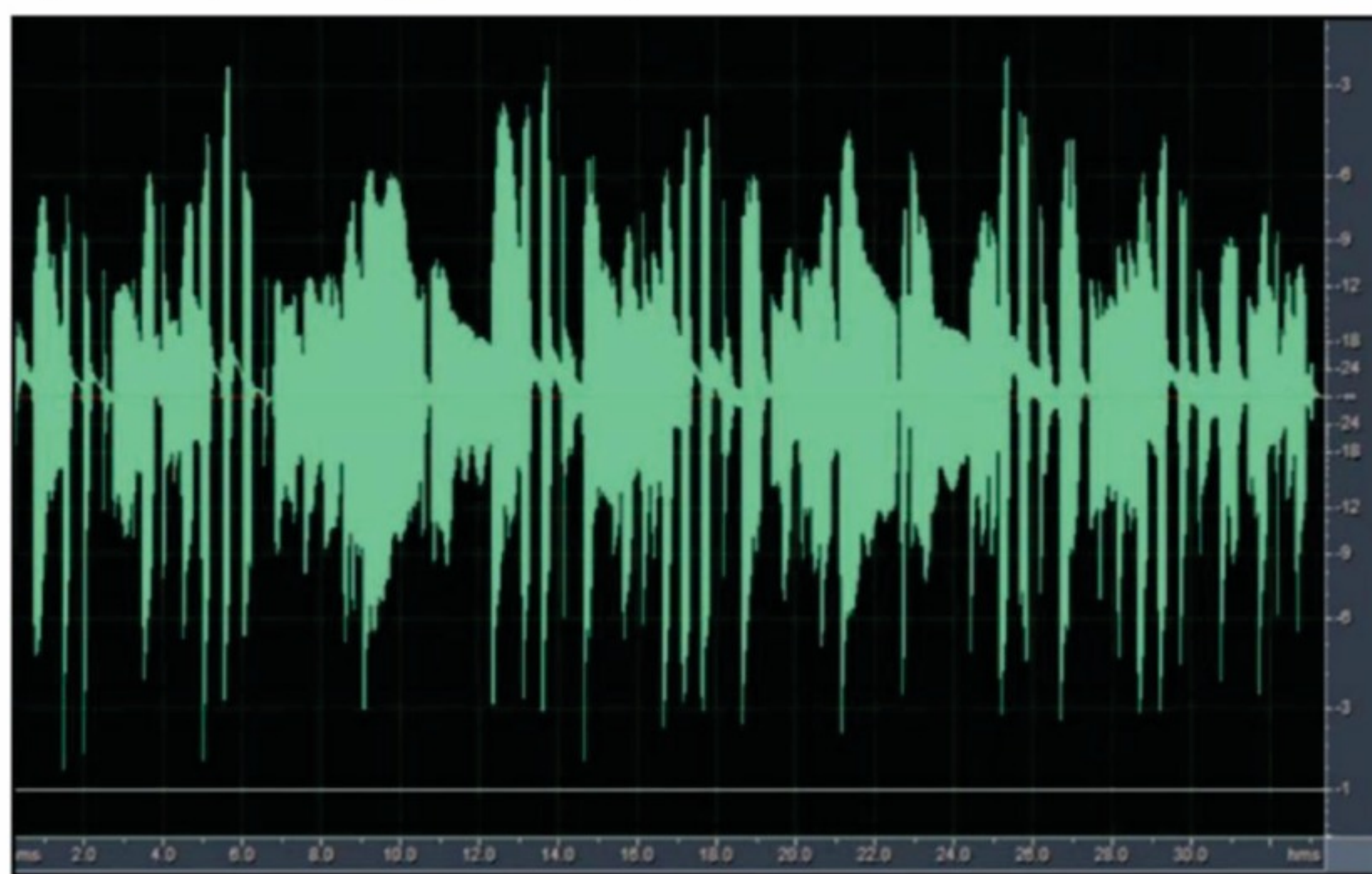


Figure 10: Output .wav file, input 300 mV peak

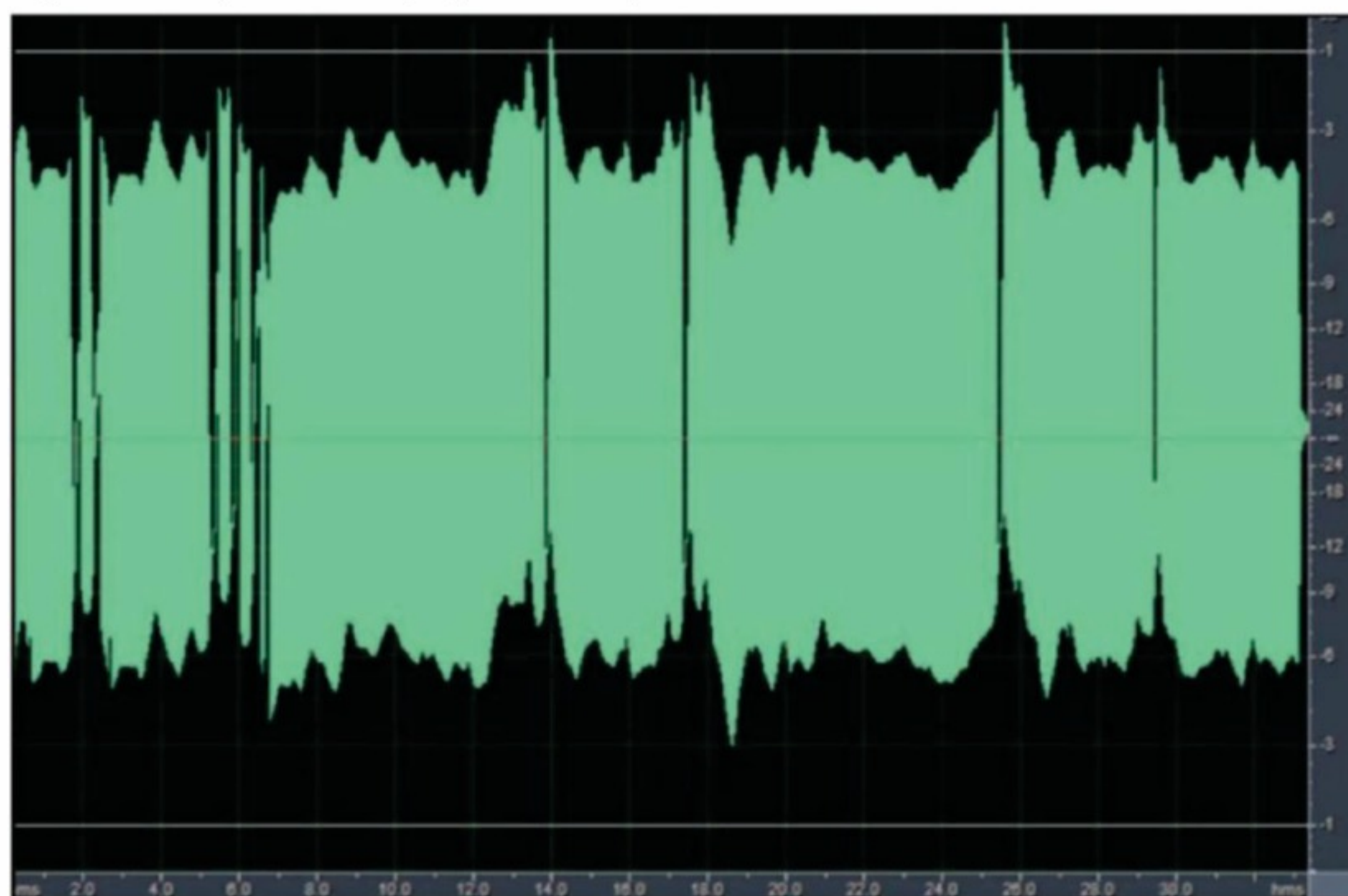


Figure 11: Output .wav file, input 1 V peak, severely clipping next stage

was observed on the lights of the adapter. The waveform is shown in **Figure 6**. Note that the maximum positive voltage is just under 0 dBV, or +1 V. (The white line indicates -1 V.) Also note that the next significant peak we see as we move to the right has a level of -6 dB, so there is a 6 dB difference between these two peaks.

Figures 7–10 show the outputs obtained from the .wav files using peak input levels of 50 mV, 100 mV, 150 mV, and 300 mV, respectively. In Figure 7, the maximum positive voltage (remember that the output voltage was scaled to stay under 1 V peak) is about -3.5 dB, and the following peak corresponding to the one we examined in the input wave is -6 dB: a 2.5-dB difference. So already, with only a 50 mV input, we have significant compression. This compression can also be observed in the envelope of the waveform. Carefully looking at the height of the peaks, you can see increased compression as the input level is increased. Listening to the .wav files, you don't notice the increasing distortion as much as a fatter sound from the compression.

Results with the Bogen AP Amplifier

Since 300 mV peak is about the maximum output you can expect from a guitar with humbucking pickups (unless very hot pickups are used), I did not extend the simulations to higher inputs. Readers of my December 2018 Hollow-State Electronics article, "A Bogen APH-1050 Turned Guitar Amp," might remember that this preamp circuit is the one I built to drive a Bogen PA amplifier having only a line-level input. The first tube in the original Bogen circuit is a pentode. If we fed the output of our preamp to this pentode stage, with the level control represented by the R10-R14 voltage divider set at maximum, we would get the waveform shown in **Figure 11**.

Listening to this, you hear a very "metal-like" guitar sound, in contrast to the compressed, only slightly distorted sound with the lower-level inputs and the level control set to avoid overdriving the last two triode stages and the pentode stage. You can see from Figure 11 that the triode preamp has given us an output with much greater amplification on positive half-cycles than on negative ones. This results from the even-order harmonics introduced by the triodes.

If you wanted more aggressive distortion in this preamp circuit, you would know that some circuit changes would be needed. And you would know this without having to desolder or solder anything, as Chad and Tom would have had to do in the days before computerized modeling of electronic circuits. 

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October 16-19, 2019

AES New York

147th International Convention

Program: October 16-19

Exhibition: October 16-18

**Jacob K. Javits Convention Center,
New York City, NY**

www.aes.org/events/147



Now solidly established as an annual tradition for the entire audio industry, and particularly for the professional audio sector, the International Audio Engineering Society (AES) Convention returns to New York City, October 16-19, at the Javits Center. As in previous years, the AES New York 2019 will be co-located with the independent NAB Show New York, open October 16-17 in an adjacent exhibition hall. AES New York registration includes access to both exhibition halls.

Honoring the convention's theme, "Inspire," AES New York promises to once again inspire attendees with a diverse gathering of top minds in the audio engineering industry, with leading Technical Program presentations and events tailored to offer attendees the ultimate professional audio education and networking experience.

As in previous years, both the exhibition (open only 3 days, from October 16-18) and the conference program (expanding to October 19) will have a strong focus on professional audio topics, including Studio Recording, Music Production, Live Sound, Broadcast and Streaming, Networked Audio, Audio for Virtual and Augmented Reality, Game Audio, Sound for Picture and Product Development, among other interests.

Last year, both the exhibition and conference program expanded significantly. The exhibition featured more than 300 brands, including over 35 new exhibitors, packed with attendees of all backgrounds and skill levels, and many free-to-attend events attracting a young but very motivated crowd also happening in the show floor and in the demo rooms. The conference program proved once again to be not only the education and peer networking event of the year for audio engineers, producers, students and professionals from all audio industry specialties, but also an invaluable resource for exhibitors and sponsors to reach those end users and industry influencers.

This year's AES New York Convention is being organized by Convention Co-Chairs Agnieszka Roginska, Valerie Tyler and Jonathan Wyner, who have assembled an expert team of Convention Committee members to hone a program covering the most talked-about topics in the industry. The AES New York Technical Program topics and areas of study include Applications in Audio (chaired by Alex Case); Archiving and Restoration (chaired by Jessica Thompson); the Audio Builders Workshop (chaired by Owen Curtin); Audio for Cinema (chaired by John Whynot); Broadcast and Online Delivery (chaired by David Bialik and assistant chair Fred Willard); Education (chaired by Magdalena Piotrowska); Game Audio & XR/Immersive & Spatial Audio (chaired by Steve Martz); Historical (chaired by Gary Gottlieb and Dan Mortensen); Networked Audio (chaired by Bob Lee); Papers (co-chaired by Areti Andreopoulou and Braxton Boren); Product Development (chaired by Scott Leslie); Recording and Production (co-chaired by Jim Kaiser, Michael Romanowski and Paul Womack); Sound Reinforcement (chaired by Henry Cohen); Student Events (chaired by Justin Chervony); and Convention Tech Tours (chaired by Jessica Livingston).

This year's AES New York Convention also introduces several new Technical Program Tracks, including Electronic Dance Music (co-chaired by Alexandra Bartles and Rick Snoman); Electronic Instrument Design & Applications (chaired by Michael Bierylo); and Hip-Hop and R&B (chaired by Paul Womack). Special Events co-chairs for AES New York 2019 are John Krivit and Lisa Roy.

Visit the KCK Media Corp. booth to grab a copy of *audioXpress* and *Voice Coil* magazines, and renew your subscriptions.

Multiple registration options are available for AES Members including the ultimate four-day All Access pass (as well as one- and two-day options) and the complimentary-for-members Exhibits-Plus pass, offering three days of AES New York exhibition hall access, demos, Project Studio Expo and Live Sound Expo presentations and much more. Visit aesshow.com/aes19audioxpress now to register and receive best possible pricing and housing options, or to find out more about becoming an AES member. And, use the Exclusive VIP Promo Code for FREE Exhibits-Plus registration: AES19AUDIOXPRESS

October 16-17, 2019

NAB Show New York

**Jacob K. Javits Convention Center,
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Located in New York City, a melting pot of content, products, and inspiration, NAB Show New York, which is produced by the National Association of Broadcasters, is the largest gathering of the media, entertainment, and technology community on the east coast. It's where insights are shared, makers meet, and creators connect—in the center of the world media capital.

With more than 15,000 attendees and 300+ exhibitors, NAB Show New York showcases the best in next-generation technology for media, entertainment and telecom professionals with conferences and workshops focused on television, film, satellite, online video, live events, podcasting, advertising, corporate A/V, production and post. As an added benefit, your NAB Show New York badge gets you Exhibits-Plus access at the co-located AES New York 2019.

October 18-20, 2019

The Loudspeaker Sourcing Show 2019

Nansha Grand Hotel, Guangzhou, China

www.loudspeakersourcingshow.com



Now in its fifth edition, The Loudspeaker Sourcing Show is becoming an established tradition for loudspeaker brand buyers, engineers, and their decision-makers to meet directly with qualified loudspeaker factories all under one roof. The Loudspeaker Sourcing Show is a three-day industry-only event, every year hosting an increasing number of attendees and exhibitors.

The show was conceived and created by husband and wife team Philip Richardson—owner of the Trueanalog Strictly OEM factory in Guangzhou, China (established to serve the international high-end and mid-fi driver and system industries)—and Mandy Tseng—daughter of the founder of Guangzhou, China-based T-yokes, top plates, and U-yokes specialist manufacturer Zeng Ben Industrial—to connect qualified speaker component manufacturers directly with businesses that need their services.

Exhibitors are there to provide OEM/ODM services for loudspeakers and related products and components. Moreover, manufacturers of every component utilized in the assembly of driver units, woofers, and tweeters will be exhibiting there, as will driver assembly houses and turnkey system factories. Furthermore, this year's show will also be playing host to cabinet factories, amplifier factories, and test equipment manufacturers.

This year, the show follows Prolight+Sound Shanghai (October 10-13) and the international Hong Kong Electronics Fair (Autumn Edition) trade show (October 13-16). Guangzhou is about an hour by ferry from Hong Kong.



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