— HORNS REVISITED —

THE EXEMPLAR PROJECT

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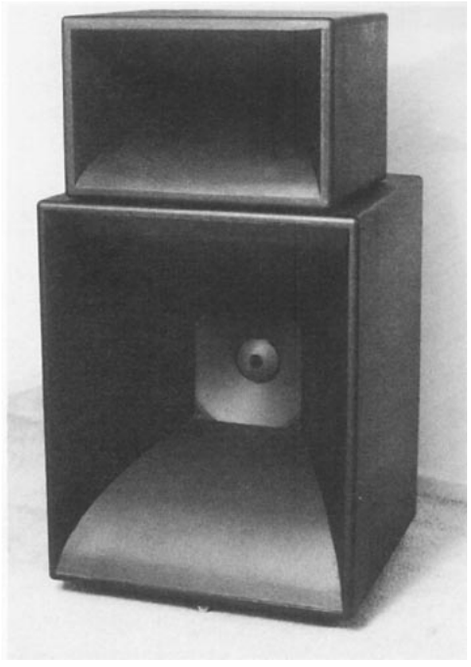


Almost Heaven

When we finished tweaking our Altec Voice of the Theater systems as described in *Sound Practices* #4 we were happy campers. A mere triode half-watt or so into those babies produced big smiles and lots of foot tapping; movie soundtracks that sounded so right; speed, dynamics! Life was good!

Unfortunately, VOT life was not perfect. There are a few major drawbacks that come with the territory when the home music listener adopts a classic Altec auditorium design. To list a few—

Size - A pair of A7s on spikes carrying 311-90 horns on top visually dominates any normal size listening room. The decor aspect of a VOT is best described as "Early Industrial Strength" or "West Coast Monolithic".

Bass - Not much below 40-50 Hz. A subwoofer or two is needed. This sure doesn't help the size issue any.

Horn Integration - The aluminum exponential and the plywood radius short horn just don't sound the same.

After many experiments, we recognized that we stiffened, damped, and tweaked the basic VOT technology well into the region of diminishing returns. To successfully overcome the remaining drawbacks meant *major* changes, a rethinking of the basic system design to the point where the result probably wouldn't look or sound much like an A7 when finished.

We needed a smaller cabinet along with a lower system tuning point to address size and bass issues. It turned out that Altec had been building such a cabinet for many years, the Model 816. The 816 is basically an A7 horn with a much smaller internal reflex volume.

Well, we built a pair of 816 cabinets (ash veneer - still in the shop somewhere) following Altec's plans, and stuffed them with ALNICO 515Bs. Next came a matching pair of boxes to house the 811 horns, with provision for filling the interiors with sand. We filled the exterior horn concavities with patching concrete and mounted a pair of 806-A ALNICO compression drivers on the resulting 811 module.

Nice looking system; small footprint, tuned at 40 Hz, crossover at 800 Hz, 16 Ohm impedance. It sounded good in most respects but the midrange was not as articulate as the A7.

The reason turned out to be standing waves created between the parallel non-flared sides of the 816 horn. With the sides at 16.125 inches the fundamental resonance was at 419 Hz. Altec avoided this standing wave problem in the A7 bass horn with non-parallel surfaces for the short horn sides. An additional effect of the parallel sides in the

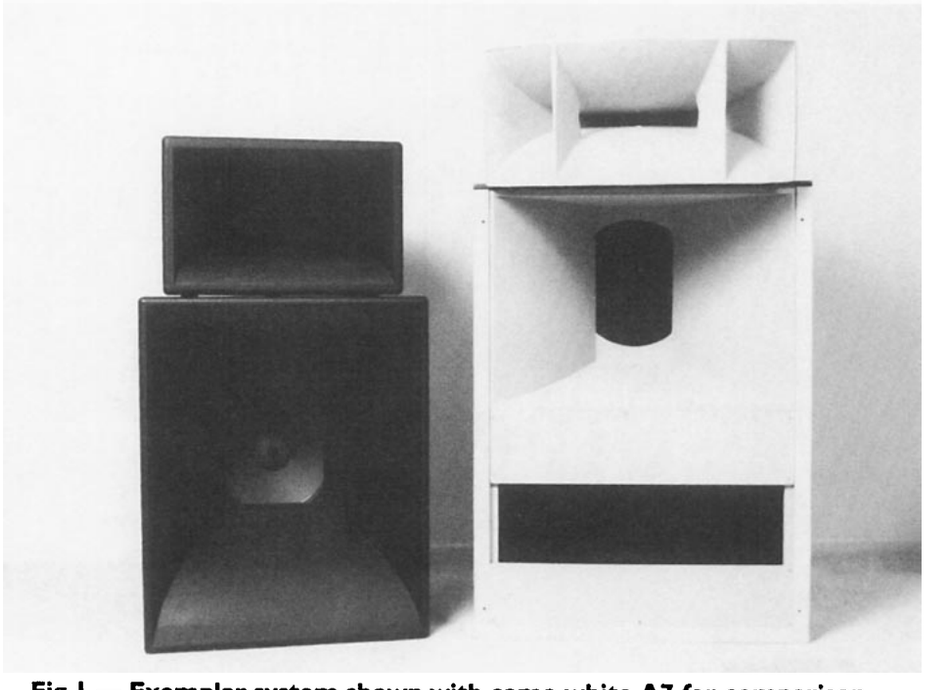


Fig 1 — Exemplar system shown with camo white A7 for comparison

816 was a higher horn cutoff due to a smaller mouth area compared to the A7, 177 Hz versus 160 Hz for the A7. These problems made a smooth transition out of horn loading more difficult.

Although our faith in the Altec drivers and horn technology was high, we slowly realized that we would have to create a system tailored to our goals to realize the full potential of horns in a home listening situation. We wanted the entire system to have a footprint smaller than an A7, offer a seamless blending of the horns, and play deep, loud, and clear on a measly triode watt or two.

Enter the Tractrix

It was during this period that we heard a full range speaker system employing tractrix horn flares for the midrange and bass drivers. The tractrix flare, although not new, has seen a resurgence of interest in the last few years thanks to the efforts of Dr. Bruce Edgar.

The tractrix expansion is unique in that it is the only horn flare whose mouth terminates at 90 degrees to its central axis. It is also the only flare that can produce a spherical waveform and it offers very low mouth impedance reflections compared to other horns. The effect of this flare is a horn that does not sound like a horn. The music is clean, clear and natural without the characteristic *horn* signature. What a difference!

We started to wonder:

- Would high efficiency, professional quality drivers excel in tractrix horns?
- Would compression drivers be suitable for use with tractrix horns?
- Would a simple two-way design be feasible and adequate?
- Would our favorite vintage drivers be suitable for retrofit?
- Could bass reflex be effectively integrated with tractrix?

We decided that working out positive solutions to these questions would bring us closer to our goal of overcoming the A7's drawbacks and improving the overall listening quality of our Altec-based horn systems.

Bass Horn Module

We started off on our design quest with bass cabinet design. In designing the bass horn we had to juggle a bewildering number of interrelated factors. The going was slow as we wrestled to produce the optimum blend of aesthetics, performance, and size using spreadsheets and CAD tools.

A few of the major factors we dealt with were:

a. Horn shape - round, square or rectangular
b. Mouth area/cutoff frequency/aspect ratio
c. Overall height to allow acceptable compression driver horn mounting height
d. Driver mounting depth to allow ease of compression driver time domain alignment
e. Optimum internal reflex volume versus aspect ratio
f. Materials and construction techniques
g. Tuning

What finally emerged from our brainstorming and number crunching activity was a freestanding, wooden, rectangular tractrix bass horn with a mouth cutoff of 135 Hz., and four 6 inch diameter rear-firing ducted ports. In order to meet our design goal of a relatively compact two-way system with extended bass response, and also utilize free standing tractrix horns to the maximum extent feasible, we decided to handle the bass below a predetermined point without horn loading. Overall dimensions of the finished product are 33" tall, 26" wide, and 25" deep and the visual aspect is far more domestic than the old A7 bass cabinet (**Figure 1**).

Since direct radiation would be important in the region where it blends with reflex energy, the bass driver would have to perform from the deep bass through the upper midrange—a span of 6 to 7 octaves. We also needed high efficiency and a reasonable reflex volume requirement.

Our initial modeling efforts concentrated on finding a woofer that met these requirements. Plot after plot of Theile-Small parameters yielded few contenders. Our favorite vintage Altecs, 416s and 515Bs were knocked out fairly early in the process due to their low mass rolloff frequencies and large reflex volume requirements.

What we needed was a driver with a huge motor, a very light and stiff cone assembly, and Fs/Qes/Vas values that allowed the best tradeoff of box tuning and mass rolloff. In a nutshell, we needed a driver designed for horn loading. Our search finally led to the current production 515-8G from Altec.

Reflex modeling for the 515-8G looked good but we were concerned about mass rolloff. Altec Applications Engineering assured us that with the light, stiff cone and large motor assembly on the 515-8G, the Fs/Qes ratio didn't tell the whole story. Altec assured us that we could expect flat magnitude response to at least 1 kHz in our application.

While we were thinking about what to do for a midrange horn, we set up a few prototype systems using the new bass module with Altec 511Bs. The unit was set up to allow flush front mounting the 511B horn with compression driver time domain alignment, and a vertical central axis height of 39 to 41 in. The 511B horns and Altec 902-8B compression drivers were installed in sand-filled boxes for mechanical damping.

We set up this prototype system for listening evaluation in four venues over several months. We tried both a stacked D'Appolito arrangement with Altec 511s (**Figure 2**) and more conventional single bass module per side with 511 compression driver horns. Listeners usually mentioned the bass modules' low distortion, high articulation, and natural transients. In smaller rooms, we got a fundamental bass response down to 20 Hz. The low end of this system got consistent praise from listeners.

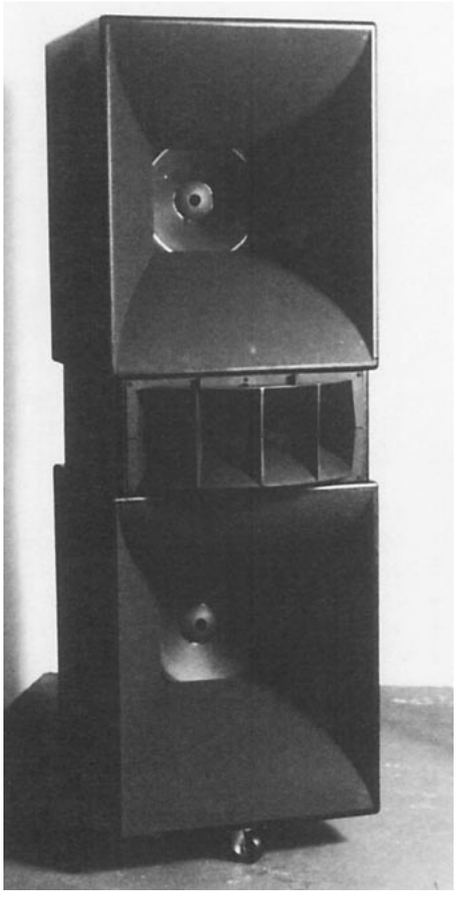


Fig 2— Experimental d'Appolito configuration using bass horn prototypes with sand-damped Altec 511B HF horns

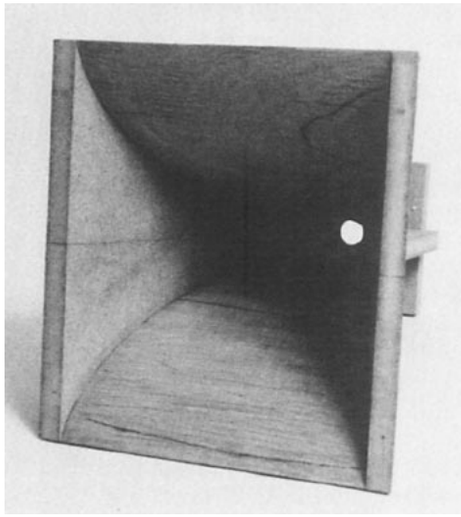


Fig 3 — Early prototype 333 Hz 35° tractrix HF horn.

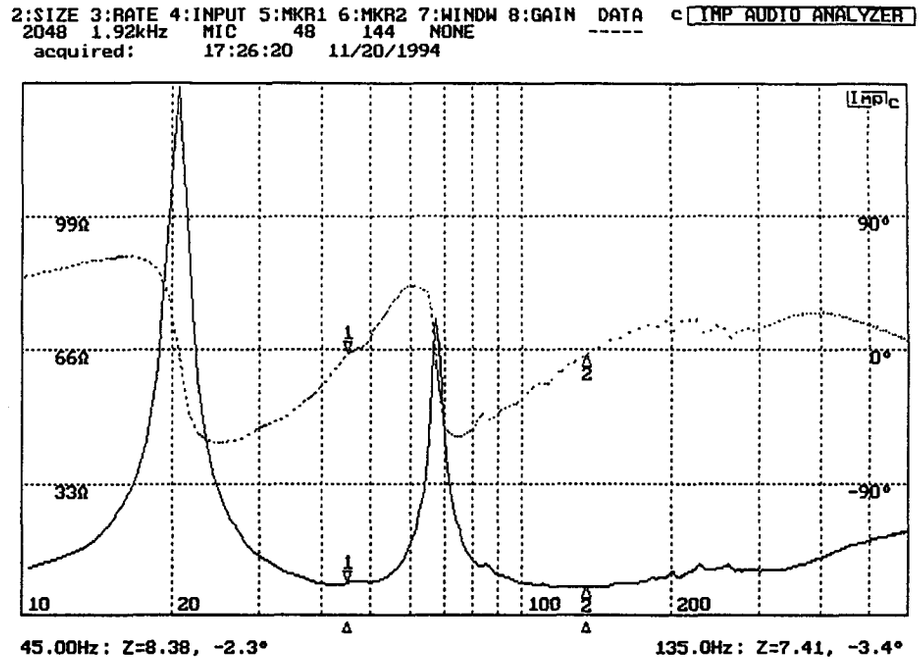
Unfortunately, comments regarding our superdamped 511B horns and 902 compression drivers were also consistent — they were way above average for 511Bs due to the sand damping but they didn't really click. Nobody could put their finger on it, but something wasn't quite right. These findings sure kept us motivated to continue our HF tractrix horn development program!

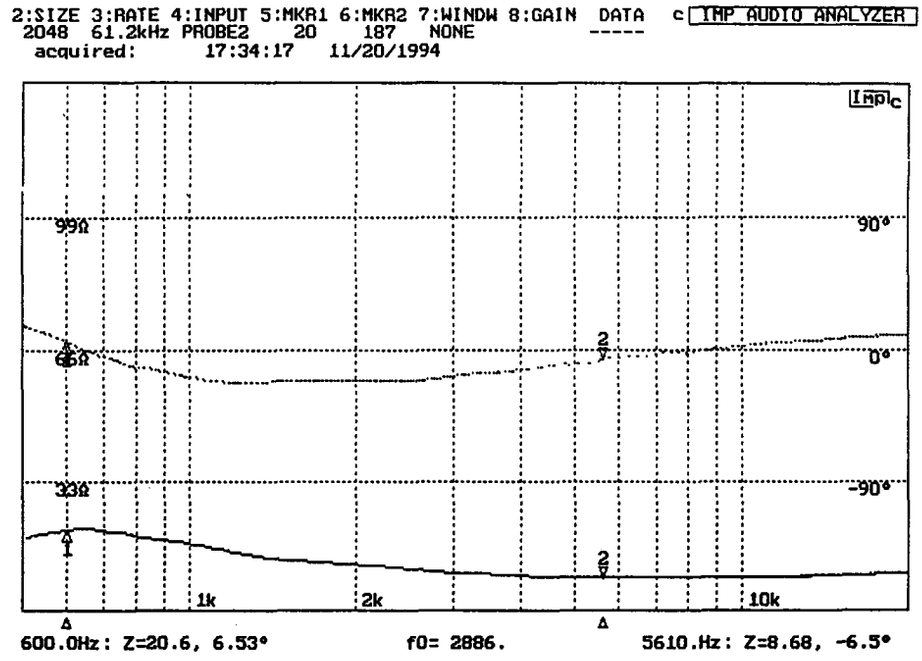
One of the big lessons we learned during this period was how different the horn profiles actually sounded from each other. And when different types were mixed, such as a VOT bass with a tractrix treble, or a tractrix bass with an exponential treble, their unique signatures were very apparent, and didn't sound well integrated. When we switched to a tractrix horn curve for compression driver loading that problem went away and the LF and HF sounded as one. The Exemplar *system* had been born.

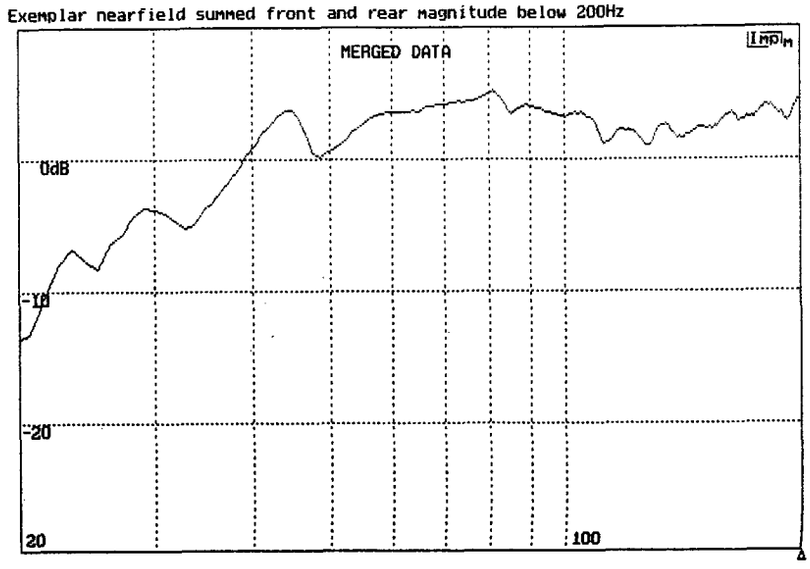
Tractrix Compression Driver Horn

The prototype tractrix compression driver horn was also fashioned from wood, covered a narrow 35 degrees in the horizontal, and had a mouth cutoff of 333 Hz. **See Figure 3.** It was obvious from the first note that it shared the high articulation and low distortion characteristics of the bass module.

Working prototypes were then produced with a wider 70 degree horizontal dispersion, which more closely matched the bass modules in coverage angle and sensitivity. The larger mouth area produced a cutoff frequency of 232 Hz. We adopted this horn







Top to Bottom

Fig. 4
Fig. 5
Fig. 6

profile for the final design as pictured throughout this article.

An interesting thing happened about this time that at first seemed to be a disaster, but eventually proved to be significantly beneficial. We contacted Altec to order some 8 Ohm aluminum diaphragms and were told they were going to be discontinued—the aluminum alloy Pascalite would effectively replace them when all stocks were exhausted. This was distressing. I had compared the two diaphragms on 802-Ds and felt the aluminum had superior extension/transient response.

Gary Jones at Altec listened patiently but was confident that the Pascalite would be superior on the 902. The major difference between the 802 and 902, aside from the magnet material, was the phase plug. The newer Tangerine phase plug (802-8G and later) was designed for more output above 10 kHz, and the even newer Pascalite diaphragm took full advantage of it. We tested and listened to the 902-8As (effectively transforming them into 909-8As). Gary was right.

System Integration

Initial testing showed few surprises. The bass module impedance and phase curves (**Figure 4**) revealed standing wave effects in the 200-250 Hertz region created by the internal dimensions utilized. The enclosure was stiffened and additional damping material was incorporated to minimize any effects. The tuning point is at cursor 1, 45 Hz., and the minimum system impedance at cursor 2, 7.41 Ohms at 135 Hz.

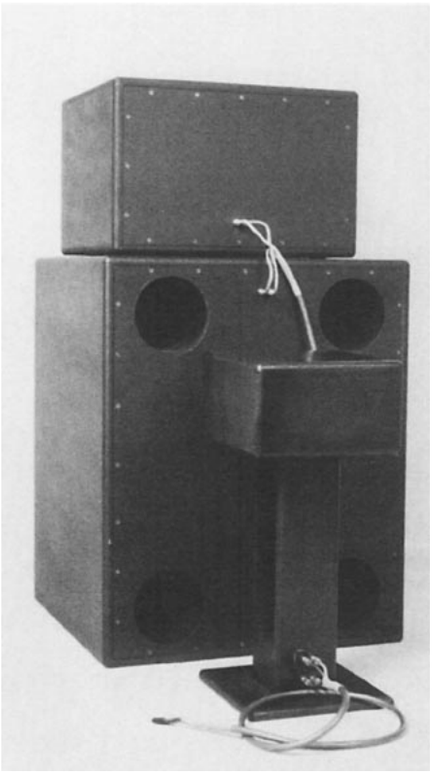
Figure 5 for the compression driver shows the passive crossover at 750 Hz, a benign phase response, and a minimum impedance of 8.68 Ohms at 5610 Hz.

A composite magnitude plot of front horn/cone and rear port radiation for the bass module is shown in **Figure 6.**

The quasi-anechoic magnitude response curve for the compression driver (**Figure 7**) reveals the basic characteristics they all share; peaks centered around 2 and 4.5 kHz and falling high frequency response. Interestingly, the tractrix did better in the extreme top end than either exponential or constant directivity horns, which were typically down by 10 dB and 20dB respectively at 20 kHz.

This peaked and rolled unequalized response is what gives compression drivers their presence and speech intelligibility and it also explains why a simple shelving control will not produce adequate results in Hi-Fi applications. If you shelve down the upper midrange to match the woofer the high frequencies are lost; if you crank up the high frequencies the upper midrange drives you over the edge.

Figure 8 indicates what we accomplished with passive equalization - same test setup, same driver. An additional benefit to this equalization was that the compression driver sensitivity could be matched to the woofer



A separate sand-filled enclosure houses the Exemplar crossover

and thus eliminate the need for series padding resistance in the high-pass circuit. The resulting system sensitivity is 103 dB/SPL @ 1W/1m.

A Better Crossover

The vast majority of two and three-way speakers are designed with passive

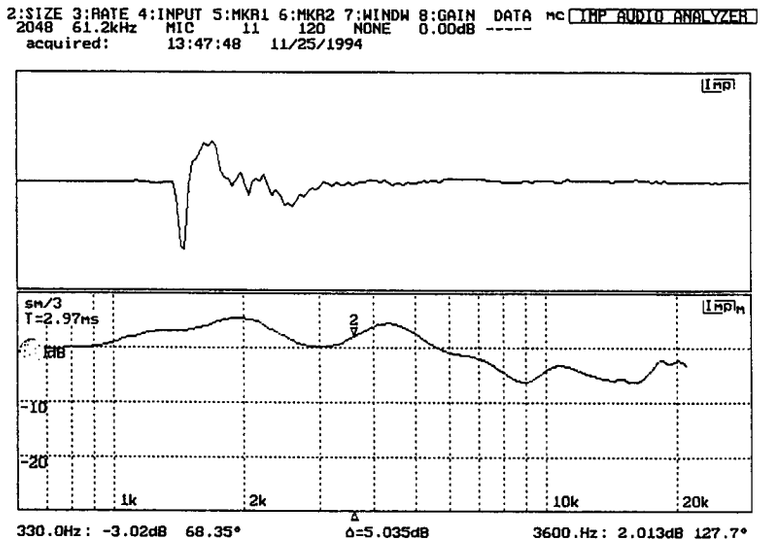


Fig. 7— Unequalized system response

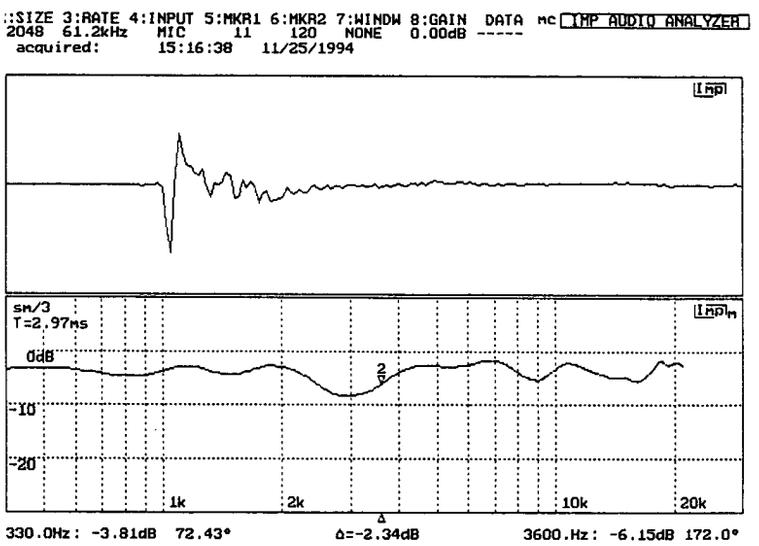
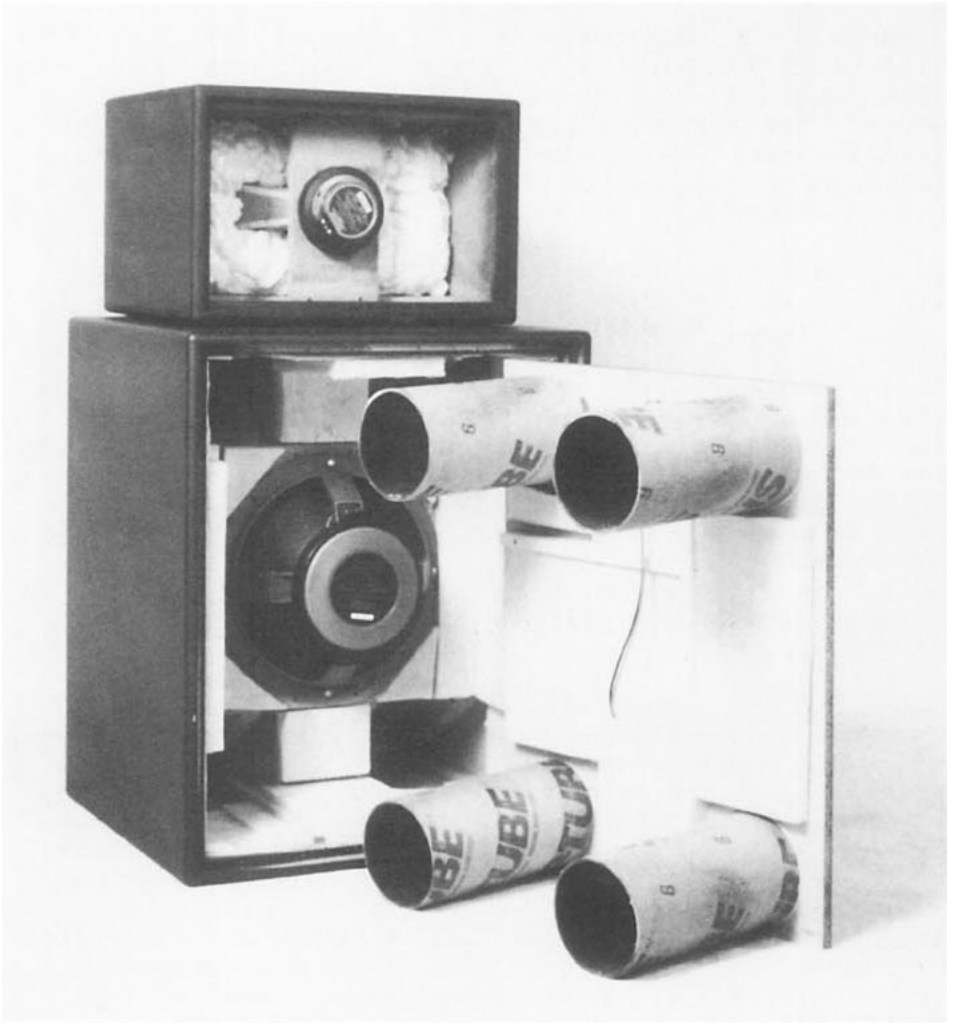


Fig.8 — System response with passive EQ



Interior aspect of Exemplar cabinets showing ducted port construction

crossovers. They are relatively simple to implement for the manufacturer and hold down cost and complexity for the user. You just plug in an amplifier and play!

Unfortunately few commercial crossovers use premium parts and bi-wiring. Even fewer can be easily bypassed to allow direct access to the drivers and not many are contained in separate outboard enclosures to eliminate the acoustic and magnetic effects of a hard working woofer nearby.

The Exemplar passive crossover was designed with all of these concerns in mind. Housed in a separate, sand-filled enclosure, it is completely bi-wired from the supplied speaker cable right up to the individual drivers. Reactive signal path components were chosen for their sonic merit — Solo CFAC inductors and Sidereal capacitors.

For cable and point-to-point wiring we selected long crystal copper developed for the Japanese super-conducting magnet program. The crossover point and slope are 750Hz and 12dB per octave, the filter type is Linkwitz-Riley. Internal enclosure wiring is also super conducting magnet type, 12 AWG to the woofer and 18 AWG to the compression driver.

Drivers

Why do we use premium drivers anyway? After all, the Altecs cost many times more than the typical drivers found in most high-end speakers. Wouldn't less expensive drivers have been just as good? Frankly, *no*.

The Altecs have a lineage that traces directly back to the Western Electric theater systems introduced in the 1930s. They deliver linearity, high efficiency, and long life. We are continually impressed by old Western Electric/Altec drivers that perform flawlessly and continue to sound excellent after 30, 40, and 50+ year "break-in" periods.
The newer magnet materials used in the Exemplar drivers aren't sensitive to temperature and mechanical shock like the older Alnico Altec motors and they aren't as susceptible to overpower problems like the old Alnicos. In short, the quality plus proven performance and longevity of professional quality Altec drivers should easily offset their higher cost. They should outlast their owners!

But how well do they work? — the inevitable bottom line, and a good question. This project didn't start out as an exercise in blending engineering and art for its own sake, although there is powerful satisfaction in turning a concept into a physical reality through innovation and creativity.

Our basic goal from the start was to fashion improvements in looks as well as sound, to better satisfy aesthetic sensibilities and to enhance emotional responses to music. It needed to work on visual and sonic levels.

Looks

The matching, complimentary, horn flares terminate at 90 degrees and then continue to quickly curve away, and at the same time into each other, via the rounded cabinet edges. Flat cabinet frontal area is simply nonexistent, the horn is dedicated to producing direct sound from the drivers. The curves lead the eye inward as well along the junction of the surfaces, and give visual form to the concept of the tractrix.

Sound

At times the speakers utterly disappear in an acoustic sense, like articles of furniture sitting mute amid sonic figures arrayed on the soundstage. They can seem totally out of place. . . we have found ourselves wondering "who parked these objects in the center of all this musical activity?"

So, after eight years of modifying, redesigning, substituting, measuring, and countless hours of listening, we finally managed to create a horn based system that does all the things we were told horns aren't supposed to be able to do. Things like deep and wide soundstaging from virtually any listening position in front of the speakers; flat, extended treble response from a compression driver, transparency; and emotional impact.

Obviously, we are very pleased with the results of our efforts. We are also pleased to be part of the resurgence of horns and triodes for home listening. By the way, some of the motivational credit has to go to the "theys" who said it couldn't be done!