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**LEGACY V** System with  
Wavelet DAC/Preamp/Crossover  
with BOHMER Room Correction

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# EQUIPMENT REPORT

## Legacy V Loudspeaker and Wavelet Processor System

### Breaking the Mold

Anthony H. Cordesman

**T**he Legacy V is one of the finest speaker systems I've had the opportunity to listen to, one of the most technically innovative, and a true assault on the state of the art. It is, however, a true speaker *system*. The speaker is integrated with a preamp, DAC, room-correction system, and electronic crossover called the Legacy Wavelet processor. This four-way system includes eight channels of DSP, 3000 watts of bass amplification, and the requisite, balanced, low-frequency connecting cable.

It is also clearly a luxury product. A pair of the speakers, plus the Wavelet cost \$49,500—depending on finish. Even if you discount that price for an excellent preamp and DAC, and consider the fact that four of the eight amp channels are built into the speakers, you'll still need to add two top-grade stereo amps and their required cables.

#### The Promise of the Legacy V for the Rest of Us

But don't let the price tag cause you to ignore this speaker. The good news for all but the wealthiest of us is that the Legacy V is the harbinger of a radical new approach to speaker performance and room correction that will soon become available in Legacy's more affordable speakers. The technology may later be incorporated in electronics that can be adapted to any speaker.

This is particularly good for me and owners of more affordable Legacy speakers, because I use the Legacy Aeris as one of my references. In fact, my only serious complaint about the Aeris has been the difficulty of having to keep setting it up, and resetting its earlier manual form of room compensation, every time I have to rearrange my system for reviews.

The Wavelet solves that set-up problem. In fact, it offers by far the easiest and most reliable set-up process of any room-correction device I know. At the same time, it goes far beyond the performance of the earlier room correction Legacy provided for the Aeris (or other systems I've tested), and produces far better results than my previous efforts to adjust room performance using various forms of room damping and reflection treatments.

The Wavelet and Legacy V take a radical new approach to a problem that potentially affects every high-end system regardless

of manufacturer and design. In fact, Legacy uses the Wavelet to address what in some ways has remained the most critical frontier in home audio—adjusting the speaker's performance to eliminate the major colorations caused by the interaction between it and your listening room, while also greatly easing the choice of listening position.

The electronics in the Legacy V also do far more than simply reduce the impact of the gross peaks and valleys that turn the bass response of speakers into the equivalent of the north face of the Eiger. The Legacy V uses the Wavelet to reduce the impact of the reflected sound and time delays that color the rest of the sound, thereby increasing soundstage accuracy, musical detail, and realism of timbre to the extent that the recording permits. Put differently, it addresses the psychoacoustic problems in room/speaker/listening-position interaction to a degree that no competing system I've heard has attempted, and it does so with striking success. Indeed, it outperforms any other approach to room correction I've heard, and delivers on the potential of digital correction to a degree that more than offsets any slight colorations coming from its presence in the signal path.

In addition, its electronics are designed to permit easy firmware upgrades—a feature that should be a basic criterion for modern digital electronics. This means Legacy V buyers face a much reduced threat of obsolescence. As I note later, it also means that buyers of both the Legacy V and the Wavelet for other Legacy speakers will get an upgraded Wavelet by the time this review appears.

#### A Brief Description of the Legacy V's Features

This has to be an unusual review in that most of it must focus on how the digital processing in the Wavelet interacts with the speaker design to provide a new approach to listening-position correction and the resulting sound. Understand, however, that the speaker part of this system is not some typical design waiting for a black box to perform electronic miracles. The Legacy V may not rival the largest competing speakers for sheer size, and doesn't require a large separate subwoofer to get the deepest bass, but it is not a shrinking violet.

The Legacy V's dipole configuration and use of passive bass radiators does reduce its size relative to the other systems I've heard with equal deep bass performance, but it is still *big*. The speaker is 6' high, about 19" wide, and 19" deep. It is very well built, designed to minimize any cabinet coloration, and weighs 226 pounds. It is definitely a two-person setup, and one I'd leave to the dealer.

It also has a fairly aggressive "techno" look with the front drivers largely exposed, a kind of sculpted metal base, and switchable, low-level blue LED lighting. I found this design to be fun, as did most of my guests, but it is not a subtle addition to room décor, particularly because its room-correction features make it possible for the speaker to work well in a smaller room than most speakers its size.

As I've already mentioned, it is a four-way system. It uses two Legacy 4"-long AMT neodymium tweeters, which Legacy says extend up to 30kHz, in a specially optimized post-convergent array. The Legacy V is the first system to use the new AMT

ribbons in this arrangement. The treble extends downward to dual 6" open-air dipole midranges, which in turn transition to the pair of 14" dipolar lower midrange/upper bass elements at the top of the cabinet. The bass is provided by a 12" aluminum driver, with a magnetically encapsulated motor powered by a built-in 500W amplifier, and the very low frequencies by a 12" subwoofer driven by a 1000W internal amp. Both amps use ICEpower switching modules. The subwoofer has an exceptionally large magnetic structure that drives three 10", mass-loaded pneumatic radiators. Legacy says the combined output of these drivers shapes low frequencies into a cardioid pattern to avoid room coloration.

The separate Wavelet electronic unit is far more than a room-correction device, although it can be used as an add-on that follows another preamp and/or DAC. Legacy describes the Wavelet as follows: "Wavelet is a preamp, a four-way crossover with time alignment, a complete speaker and room-resonance correction system, and a high-end DAC with apodizing ability. The preamp and DAC can also be bypassed at the touch of a button. Wavelet debuts the revolutionary Bohmer acoustic processing to optimize the loudspeaker/room acoustic transfer function in both the frequency and time domains. Employing new algorithms, it starts with a psychoacoustically based measurement method with the provided calibrated microphone. Alignments are then individually optimized within an unprecedented 40ms window by way of a wireless iPad, smart phone, or computer. The result is audibly improved transient response that allows the V system to operate accurately and consistently in any listening environment."

I'll get to how all this affects the sound shortly, but when it comes to the technical details, the Wavelet is relatively compact for what it does. It is 17.52" wide by 3.74" high by 11.85" deep, and weighs only 13.5 pounds. It has two separate pairs of XLR and RCA analog inputs—each with a trim control to equalize volume between inputs. It has SPDIF (RCA) and optical (TosLink) digital inputs with 24-bits/192kHz capability for the SPDIF inputs and 24-bit/96kHz for the optical. (The actual DSP is an Analog Devices processor with an internal processing sample rate of 96kHz and bit depth of 56 bits.)

A word about these 24-bit/96kHz+ input and processing limits, which not only apply to digital signals but also to analog ones (which must be converted to digital to feed the room-correction system). Legacy recommends a conversion tool such as JRiver if you are driving the Wavelet with a computer playing DSD files, and makes the valid point that almost all DSD recordings have to be mastered using PCM anyway. I'm a fan of SACD because some great modern classical recordings have been made using it, but I find the DSD fetish to be just that. If there is a difference, I've never heard anyone demonstrate it under controlled conditions.

As for the rest of the Wavelet features, there is an XLR input for the room-correction mic, and an Ethernet interface for room correction and firmware updating. There are also four XLR outputs per channel: one for the subwoofer amplifier (internally powered), one for the bass (internally powered), one for a user-provided lower midrange amplifier, and one for a user-provided midrange/treble amplifier. The good news is you get two sets of 15-foot XLR cables with the speaker, and Legacy says amplifiers of 60W and 30W are good for the midrange and treble inputs, respectively. (Oh, and yes, the sonic nuances of your particular choice in power amps will still

be audible in spite of the room correction.)

Finally, there is a small, basic remote volume control, but what counts is the Wavelet app for both setting up and operating the system. The Web-based remote app worked on both an iPad and iPhone, although my iPad kept dropping out and required some tweaking to reinstall the app. The app's features were very good and the installation option was exceptionally easy to use. Setup is quick and automated, and avoids a dependency on exact positioning of the set-up microphone.

You can control volume very precisely, choose inputs quickly, do some minor boosts and cuts, and switch on/off three correction features: room correction, apodizing (removing pre-ringing in the digital filter), and low-frequency crosstalk. To adjust individual recordings as required there are three faders for bass-frequency contours centered at 40Hz, 80Hz, and 160Hz, and a lower treble control centered at 5kHz. I would additionally like to see a balance control to make minor adjustments in the soundstage. Legacy tells me this is now being developed.

## The Sound

When it comes to the sound, I'm going to take a different approach from my normal reviews. The Legacy V is still a very good speaker system even if you turn the room-correction feature off. It has extraordinary frequency range, low- and high-level dynamics, and exceptionally natural musical detail. The deep bass will still go down to subwoofer levels, although the overall bass response will be far more ragged. The highs will still be extended without any apparent rise at the top or touch of hardness, and the speaker will still provide an excellent soundstage with good definition, image size, width, and depth (although one that does not approach the nuances and realism of the sound with the room-correction features on).

That said, you aren't going to buy this speaker as if it were a conventional transducer. It is the very nature and sound of the room correction that define it. The combination of the Legacy V and the Wavelet involves so many processing options tailored to interact directly with the speaker—and so many innovations in room correction—that I've asked Bill Dudleston to provide a short description of each key feature and what he was seeking to accomplish in musical sound quality. I've then done my own listening to validate or criticize them as objectively as possible.

## What makes the Legacy V system different from other high-end speakers?

*Dudleston:* The Legacy V system projects a carefully controlled radiation pattern to greatly reduce early reflections. This widens the acceptable listening area, improves stereo imaging, and helps to properly place sources front to back. The ambience of the recording hall is more present and the room colorations are diminished. Most importantly the radiation pattern is an ideal candidate to maximize the benefits of DSP.

- The Wavelet's DSP system restores the natural free-field separation at low frequencies, which is otherwise bounded by the room's physical dimensions.
- The V system's directivity pattern prevents early reflections from masking the recording venue.
- The V system with Wavelet reconstructs the natural low-frequency separation occurring within the first 14ms. (Any cut

# EQUIPMENT REPORT - Legacy V Loudspeaker and Wavelet Processor System

from *Dick Hyman/Age of Swing* will reveal the wider and deeper soundstage benefits.)

- The Wavelet processor's Bohmer Audio Room Correction virtually eliminates the problematic effects of reflections and resonances throughout the listening field over a 40ms window. (The opening plucked bass from Holly Cole's rendition of "I Can See Clearly Now" from *Don't Smoke in Bed* demonstrates this all over the room.)
- The Wavelet processor virtually eliminates digital pre-ringing of brickwall filters via apodization. (Defeating the apodization by placing the DAC control in the linear mode will demonstrate the digital hash that was present.)

*Cordesman Assessment of Impact on Sound:* From the practical viewpoint of an audiophile, the combination of the Wavelet and the Legacy V does achieve several goals. One is that the Legacy V with the room correction on provides an unusually large listening area. This area involves only a minimal shift in low-frequency sound as you alter listening position height, or move away from the wall, or to the sides and even to the corners of the room. It also provides very good upper-octave response over a wide area without the beaming effect or directivity of designs that affect upper-octave energy and parts of the soundstage with limited head movements.

I'll get into the impact of the room correction on the music shortly, but in summary it does an exceptional job of reproducing the sound of given venues, as heard within my limited collection of chamber music recordings in local homes and halls I know quite well. It also does an exceptional job in symphonic music of reproducing the sonic characteristics and ambience in two concert halls very familiar to me.

As for the apodizing filter, about all I can say is that the overall digital processing sounds very good and is competitive with DACs that cost as much as the entire Wavelet, but is not quite as clean as the very best and most expensive DACs I've heard. The apodizing filter feature is switchable. Using it, I rarely heard a difference; nonetheless, I would make sure to keep it switched on to correct the more audible pre-ringing in some recordings. (Some older CDs have more audible problems that using the filter does reduce.)

## How does the radiation pattern and driver technology affect given aspects of the music?

*Dudleston:* How a speaker radiates into a room and the rate at which it starts and stops are the primary building blocks of its sound character. Whether reproducing the delicate texture of brushes on a snare or the growl of a bass, these characteristics are dependent on the precise tracking of the recorded waveform. The advantages of using multiple synchronized drivers with increasing radiating surface with falling frequency are large. This allows each driver's bandwidth to be specifically optimized for its musical range.

Since the sound of music is the change of pressure level over time, it is self-evident that the ability to change levels quickly without limitations is key to dynamic performance and transient decay. This is where the V system can really shine. First it has approximately three times the diaphragm area of a high-end speaker with a pair of 8" lower-mids. The neodymium magnet

structures provide a very intense restoring force. By overdamping the driver slightly, the high power provided by the amplifiers can be applied to overcome the added stiffness of the suspension for a faster decay. This is another advantage of the DSP, as we can control the voltage output precisely.

Using solid cast driver frames, premium motors, optimized magnetic gaps, and careful diaphragm selection are key. If one gently taps or rubs each cone diaphragm, one can literally hear the range for which it is optimized.

*Cordesman Assessment of Impact on Sound:* The overall integration of the wide mix of drivers and driver locations is nearly seamless and—as is true with every really good speaker—you would never know how complex and large the Legacy V is from its sound.

The Legacy V has a very clean presentation without any of the artificial emphasis in the upper midrange that can sometimes give the impression of a "clean" sound, but at the price of natural timbre in the strings and woodwinds. The speaker's overall timbre is slightly warmer than that of some competing speakers, but its response is very extended, and dynamic detail is exceptional and more realistic at low and high levels with the room-correction feature on, and is about as musical and natural as the recording permits.

## Explain the advances in the new dual 4" AMT (Air-Motion Transformer) ribbons. What does this do to given aspects of the musical listening experience?

*Dudleston:* The 4" AMTs are capable of a more extended frequency range and slightly greater efficiency. The top end of the V system was given some pretty arduous requirements. Besides being sweet and non-fatiguing, while moving air 32 times more effectively than a 1" dome with the same diaphragm travel, it has to pass the "sit down/stand up" test for vertical coverage without combing issues. Next, it has to radiate over a 60-degree horizontal window without the top end dropping off, and lastly (most uniquely) it has to have greatly reduced level outside that angle across its range.

To pass the vertical test, the diaphragm height could not exceed 1". After months of ideas and experimentation, two 1" x 4" AMT drivers were butted end-to-end horizontally. We knew this could achieve the reduced levels off-axis as the array was larger than the longest wavelengths it would reproduce. Next, the outside edges were brought forward in increments, allowing the ribbons to crossfire. They were adjusted carefully to provide the desired window of coverage, the leftmost driver providing the highest-frequency coverage to the right extreme of the listening window, and vice versa. The center summation was quite solid, as it should be, but an added benefit was the mutual coupling at the lower end of the ribbons' range, increasing efficiency and decreasing distortion even further. If the ribbons were not splayed as described, they would comb filter at higher frequencies. But because the diaphragm is moving away from the listener as it approaches the center, combing is not a problem. Ironically, the 6" drivers just below the ribbons intentionally rely on destructive interference off-axis to reduce their level.

*Cordesman Assessment of Impact on Sound:* I thought the simpler version of this driver in the Aeris was excellent, and it sounds

even better in the Legacy V, although it is impossible to separate out the sound of this driver from that of midrange/midbass driver, the electronic crossover, and the other features in the Wavelet.

I've not always been a fan of AMTs, but this one is very, very good: tight, fast, and transparent with the natural life and air the best recordings provide. It competes directly with the finest competing ribbon, electrostatic, and dome tweeters I've heard, and the integration of the upper midrange and treble is exceptionally realistic and musical.

As I noted earlier, the combination of the AMT and other drivers in the Legacy V does an exceptional job of providing a wide listening area and natural soundstage on those recordings which have a natural soundstage. Upper-frequency performance was very good on test tones, and frequency response amplitude measured very well—far beyond the limits of my hearing.

### **What are the reasons for the dipoles?**

*Dudleston:* The primary reason is as a steering mechanism. The technique provides better transient behavior and more snap. The goal is to reduce the angle of sound radiated in the room. The dipole by nature creates acoustic nulls to each side. It also radiates out-of-phase energy to the rear so that the rear reflections do not add constructively to the front radiation. In the midbass range the rarefaction of the dipole erodes the undesired bass leakage to the rear from the upper bass driver. As with microphones, an omni and a figure-of-eight combine to form the desired cardioid pattern, rejecting rear energy.

*Cordesman Assessment of Impact on Sound:* The sound in the lower frequencies is very good in transient detail and apparent speed, but I have no way to assess how much of this is due to the design features Bill Dudleston describes.

### **What is the musical rationale for large bass active and passive drivers and 1500 watts of power?**

*Dudleston:* When one ponders the size of a kettledrum, double bass, tuba, or Hartke bass stack one can see why lots of piston area on a loudspeaker is important. Musically speaking, *four times* the air displacement is required for each musical octave lower in pitch. For a woofer to have a deep voice naturally, it must have a good amount of mass or very little damping. To have both a deep voice and good damping, a tremendous amount of power is required to overcome stiffness and inertia. The V system uses massive motor structures and weighted acoustically coupled radiators to accomplish the needed damping and deep tuning without adding port turbulence at high levels.

*Cordesman Assessment of Impact on Sound:* If you wonder if high power, large driver size, the right crossover, and the right cabinet really count with room correction to sharply reduce room-caused peaks and valleys in the bass, just try the Legacy V out with really deep test tones, synthesizer, bass guitar, etc.

The combination of large multiple drivers and plenty of amplifier power really pays off. The control of resonant peaks made possible by room-processing features described shortly also means you hear far more of the deep to upper bass in the way the signal is meant to be heard, and not the usual mix of

peaks in the more audible portions of the midbass, and suck-outs in the upper bass or lower midrange. There also are fewer problems with audible room resonance and vibrating objects sensitive to the particular bass peak in a given room. Great for those few organ records that go really deep.

### **What are the advantages of an electronic crossover?**

*Dudleston:* Generally, improved resolution and transient response are the most obvious benefits of connecting a speaker driver directly to the power amplifier. Component losses are eliminated, and crossovers are much more precise.

Even with the best quality passive components, there is a small degradation of sound for every component you put between the power amplifier and the speaker driver. Even a simple inductor adds resistance. The real benefit of eliminating passive crossover is that the passive filters are impedance-dependent by nature. To compensate for impedance variations, power is dumped to ground, reducing amplifier headroom.

With a DSP-based crossover it is possible to add as many stages or filters as required without accumulating losses. You have a vastly superior toolbox available to improve a driver's response, align it in time, and create truly complementary crossover slopes throughout the system.

There are some important advantages that digital can hold over analog methods that are worthy to note. The obvious one is that the signal can be compensated in the time domain with surplus dynamic headroom. But there is also an overlooked advantage. When there is a multitude of complex theoretical correction blocks for the loudspeaker, crossover, room, apodizing filter, and low-frequency crosstalk, the powerful elegance of simply inserting the computed coefficients into a single algorithm without multiple circuit stages via DSP really pays off. With the Wavelet, except when you are using the analog inputs, you won't even be introducing an additional conversion stage. Not only did you *not add* more circuit stages to accomplish this, you actually eliminated the weakest components in the signal path: the passive components of the crossover.

*Cordesman Assessment of Impact on Sound:* I can only agree in theory. I have no idea what a Legacy V with a traditional crossover would sound like.

### **How does the Wavelet Bohmer approach to room correction differ from others?**

*Dudleston:* It's all in the timing. The sound of music is created by varying air pressure over time. To weigh just how important time is to music, consider the units of measure for frequency or pitch (Hz) are cycles *per second*. So it must be well understood that precise timing in the arrival of energy is fundamental to accurate musical reproduction. Vary a turntable's platter rotations/time, and the pitch changes. Change the time between notes and the tempo changes.

Anyone measuring a loudspeaker with conventional methods in a listening room quickly learns that obtaining a measurement that correlates to how the loudspeaker sounds is virtually impossible. The measurements vary greatly with the location of the microphone. Measuring the speaker at a number of locations about the room to create an average response may generate a

# EQUIPMENT REPORT - Legacy V Loudspeaker and Wavelet Processor System

generalized plot, but will not incorporate precise time domain data. One cannot logically omit such vital timing information when correcting a loudspeaker to a room.

Ironically, it is in the time domain that we find the real solution to the problem. It is the combining of multiple arrivals that cause problematic response dips and peaks. The room is dominating the decay of power. As a result the anechoic “flat” speaker may exhibit boominess or muddiness, and transient hangover. Attempting to equalize the response without regard to the time domain will actually compound the response errors at other points in the room while creating new time domain errors at the listener position.

The key differences are:

- The algorithm relies on psychoacoustic weighting (how we hear) and how the sound sequentially arrives to us.
- The applied correction is not sensitive to position. Transient behavior is improved on- and off-axis.
- Microphone placement is similar to how you record an instrument, at a distance of about four feet from the speaker on a direct path to the listener. The objective is to measure how the room is loading the speaker by measuring sound pressure over an event window up to several hundred milliseconds at each frequency.
- The measurements are readily captured and exported to a dedicated website where a super-computer performs many thousands of iterative calculations to determine the optimal correction solution.
- After the correction algorithm coefficients are rendered for each speaker and automatically downloaded into the processor, the processor can apply the correction in real-time over a full 40ms window.

- Psychoacoustic weighting is emphasized in the calculations. The time domain *is not* compromised to fill minor dips in the response curve. The hearing mechanism is given adequate, accurate cues and left to perform its tasks. Aligning the energy in time is what smooths the response curve, not power equalization.

*Cordesman Assessment of Impact on Sound:* First, I should note that setup was exceptionally quick and easy, and not tied to a particular listening position. I've had quite a bit of grief getting good results with some other systems that required multiple setups to test different microphone locations. I would, however, try out the Legacy V with the room-correction feature turned off to first find the best speaker location without it, and then apply the DSP to that setup.

Also, if you do audition this speaker be aware that switching the room-correction feature has the apparent effect of slightly reducing volume. You can't just A/B.

That said, I've already stressed many of the advantages of the room-correction features, and I should emphasize that I use it with the Legacy V speakers placed in areas in my room with minimal resonant effects. In some ways, this means the benefits of room correction are lower

## SPECS & PRICING

**Type:** Frequency and time-domain optimized, four-way, directivity-controlled loudspeaker

**Frequency response:** 16Hz-30kHz +/-2dB

**Driver complement:** Dual 4" AMT tweeters configured in post-convergent array; dual 6" curvilinear upper midrange configured in dipolar array; dual 14" carbon/pulp midrange/midbass in dipolar pattern; 12" aluminum-diaphragm woofer in sealed enclosure; 12" aluminum radiator subwoofer driving three 10" mass-loaded pneumatic radiators

**Impedance:** 4 ohms

**Sensitivity:** 98dB @ 2.83V/1m

**Crossover:** 80Hz, 400Hz, 3kHz

**Recommended amplification:**

Two external channels of 30Wpc or greater

**Dimensions:** 18.75" x 72" x 19"

**Weight:** 226 lbs.

**Price:** \$49,500 (with Wavelet processor)

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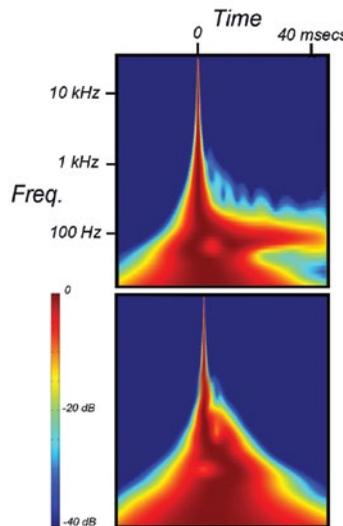
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than would be the case in most rooms, and certainly lower than in problem rooms—few of us can build a house or listening room around our systems.

In most setups, it is clear that the overall mix of room-correction features with good acoustic recordings will not perform some sonic miracle. They will, however, provide an improvement in the clarity of the music over a wide range of frequencies, an increase in soundstage depth and imaging, and an audibly clearer lower midrange and mid-to-upper bass.

This is particularly apparent with the bass viol, cello, piano, lower woodwinds, guitar, and natural-sounding percussion recordings, and also in clearing up vocals, naturally staged operas, and choral music. It is also far more apparent with really good recordings. No system can make up for what is not there in the first place. The Wavelet can't fix what isn't miked naturally for location and realistic soundstage, although the sound of crowd noise and applause sometimes does become more natural.

I should stress that the sound of the best conventional speakers in a really good system with a really good setup is still very competitive in overall quality. Moreover, every audiophile has his own preferred set of nuances and sound characteristics, and no system can be all things to all audiophiles. At the same time, the room-correction features have real advantages that do make both the speaker location and listening position far less critical.



Respecting the Time Domain

Correcting a loudspeaker response exclusively in the frequency domain introduces large errors in the time domain (top). Note the lingering energy in the bass and lower midrange.

The Bohmer correction method (bottom) smooths the frequency response by emphasizing correction in the time domain. Note the energy is moved back in time to the original event, improving definition and reducing coloration from time smear.

**What kinds of frequency and timing correction are being applied, and what are their limits relative to making everything flat?**

*Dudleston:* We address the sequence of reflections from boundaries that occur in the first 40ms. The correction works almost entirely in the time domain. The time-corrected response is always smoother but never ruler-flat. The bass will be deeper with faster decay. Vocals will be full, but not chesty or weak from the floor bump and dip that nearly always occurs.

Sonically this translates to a more natural transient. If an actual drum is struck, the initial sharp transient pulse will be felt as well as heard. Conventional speakers without controlled directivity and proper room correction can smear the event in time, compromising tautness. This is readily evidenced by defeating the room correction, even on the highly controlled V system.

The loudspeaker and crossover are matched carefully to the target function before the speaker leaves the factory. Each section of the speaker is already compensated by the Wavelet in time *before* room correction is applied. Frequency adjustments are gently applied to each of the drivers with respect to time domain. The speaker is minimum-phase in behavior and the response quite smooth. While we have the luxury of already knowing precisely what the speaker is delivering acoustically into the room from the floor up, even at what radiation angle it is being launched, the room still gets the last word. As room boundaries are closer than one-quarter wavelength, the radiation efficiency actually increases with initial reflections. As the frequency rises, cancellations begin to occur. Corrections for these phenomena are not accomplished by boosting or cutting the amplitude, but by literally pushing the late energy back to the original event. Both the significance and audibility of these corrections decreases progressively above 500Hz in most listening rooms.

We have learned that notch filtering of resonances is not a solution. When a dip is boosted in the power response, so is the reflection that caused the dip in the first place. Amplifier power is wasted, the speaker works harder, and the time domain is corrupted. Many of the nulls and buildups we experience are not from resonances at all, but instead from reflections interfering with the direct path to the listener. Remember that multiple reflections are required to create a resonance, so the time required for them to generate is significantly longer. Resonance and reflection behavior is quite different and should be treated accordingly. Automated equalization of the power response is treating a symptom, not the cause.

A chief problem in correction systems lies in the unevenness of sound throughout the room. It originates because of the way correction systems treat the different resonant phenomena within the room. They tend to disregard the origin of the resonance, treating them all in an equal manner. This is a mistake because resonances with different origins have radically different behavior.

Major fundamental problems exist in previous room-correction systems. Some devices take an acoustic snapshot, compare the input and output, subtract the difference and then add it back into the input in a polarity-inverted fashion. That would work if it were a steady-state matter and didn't create a huge error in the time domain. The measurement is also totally dependent on the sample window. If we were to take twenty different sample measurements from the same burst source just 1 millisecond apart, we would get

twenty different correction solutions as the reflections arrive at the microphone.

Other systems ask you to make measurements at up to six different locations. However, the person close to the sidewall experiences dips and peaks at different frequencies than the person in the sweet spot. Homogenize this data and the time domain information is destroyed. Temporal cues are lost and neither listener position is optimized. Another method is intended to be precise for a single listener position. It uses a cancellation technique fixed to a set path to the listener. It requires the listener to maintain a relatively static head position. The system does not recognize or treat room resonances, and actually increases errors apart from the listener location.

Not surprisingly, each of these methods results in an unevenness or unnaturalness in the sound about the room. The Bohmer method captures the wavefront as it is building in time. It collects a more useful and accurate sample over a longer period and distinguishes between direct sound, reflections, early resonances, and later resonances. Measurements are made closer to the speaker and over an extended time interval to detect how the acoustic waves are actually building in the path toward the listening area.

There are the resonances associated with the room's physical dimensions that are relatively slow-developing phenomena more loosely connected to speaker output, and there are resonances due to the loudspeaker's relatively close proximity to the room's walls, floor, and ceiling that are intimately connected to loudspeaker output and behave completely differently.

*Cordesman Assessment of Impact on Sound:* I've lived with a wide range of other room-correction systems, and used TacT, Meridian, DSPeaker, and Audyssey units in my reference system at different times. I experienced set-up problems in each case, and at least some of the listening problems that Bill Dudleston highlights—which include quite measurable changes in the bass response with surprising small shifts in microphone position, or listening position, or height or width—and even in room correction when the frequency range of the room compensation is limited to lower frequencies and correction of dips in the response is also limited.

All of the better competing room-correction devices I've tried could be made to work well in dealing with serious bass-response problems, but their time and phase correction seemed somewhat problematic with really good, natural, acoustic music recordings and systems. In practice, they often work quite well with soundtracks and videos, but the sound is not as clean with most speakers as the sound without correction can be from speakers that are time-aligned and have minimal phase problems.

The Wavelet-Legacy V system did better in all respects than any other DSP system I've tried. I'm far from certain that this aspect of audio will not see further major improvement over time, but you can't buy or hear the future now. And, the firmware upgrade features of the Wavelet mean that such progress may end up being only one download away.

**Explain the impact of the Wavelet's Bohmer Correction eliminating unwanted delayed signals in terms of the music listening experience.**

*Dudleston:* As music is pressure amplitude varying over time, the less time smear, the better the sound will be. Timing distortions

# EQUIPMENT REPORT - Legacy V Loudspeaker and Wavelet Processor System

weaken the musical message. If the speaker's ability to stop is improved it will invariably become a better speaker. The Wavelet improves the speaker's ability to stop.

The corrected speaker sounds clearer, has higher resolution, better transient impact, and more accurate timbre, and generally conveys the emotional message of the music to a higher degree. Which one of these properties you notice first will depend on your personal listening biases, but they are all present and closely connected to the time domain behavior of the speaker.

Furthermore, with the Wavelet's Bohmer Correction you don't have artificially added time smear that's usually present with other room-correction systems. This smearing obscures the musical message. Usually this artificiality manifests itself as a lack of ease. Sometimes you can't quite put your finger on it until it is removed.

A properly corrected speaker system will produce an even soundfield throughout the entire listening room with improvements to the time domain manifesting themselves as enhanced clarity, resolution, transient response, and timbre across the space. The improvement is easily verified by walking around the room. It is not a subtle effect because errors in the speaker/room interface are not small. Once experienced, your brain becomes critical of uncorrected systems and the lingering transients. The sonic result is smooth and natural-sounding without artificial color.

*Cordesman Assessment of Impact on Sound:* I would again agree in regard to the room-correction systems I've lived with, but here I want to reinforce the qualifications I just made earlier. I've scarcely heard every option, and it has been some time since I've heard the latest Audyssey and Meridian systems.

Good as the Wavelet and Bohmer corrections are, I've also heard speakers like the Wilson Audio Alexia and YG Acoustic Hailey perform competitively in the same room in my home with really good conventional audio components and proper setup and speaker location. I've also heard the latest Vandersteens and Magnepans provide further demonstrations that sonic clarity and excellent performance are not room-correction dependent.

Those qualifications made, I was truly impressed with what the Legacy V could do in making subtle improvements in the realism of imaging, the definition of image size and depth, the smoothness and clarity of the bass with a wide range of classical music and acoustic jazz, and not simply with modern recordings.

I found this out listening to a Bernstein recording of Beethoven's Sixth Symphony when I casually turned the Wavelet's room correction off just to hear what would happen. To mix a metaphysicism, the result was scarcely the musical difference between night and day, but the improvement in overall clarity was immediately apparent. The same later proved true with Modern Jazz Quartet recordings and many others—including the Eagles, Stones, and Jennifer Warnes.

The one exception to the value of the room correction was with the kind of pop recording that had been engineered to have a constant wall of sound and volume/dynamic level to increase its punch for radio play and other purposes. I'm biased against such recording, however, and it may well be that the only device that could ever improve such music to me is the off switch.

I'd also caution that the clarity coming out of the Bohmer

correction can potentially have an initial negative impact if you have gotten used to listening to the resonant peaks in your system. You may initially feel you hear less bass, although a little patience will reveal the music now has a wider range of bass frequencies, more realistic detail, and smoother upper bass and lower midrange. Cello music is a good example, as is the lower register of the guitar. As for the rest of the music, I have no caveats.

## Coming Upgrades and Follow-on Availability of the Wavelet

The Legacy V's firmware is not only upgradeable; Legacy is already finalizing an upgrade to the current firmware that will rearrange the Settings menu on the WiFi remote to make installation of the loudspeaker system easier. The Room Correction sub-menu will only contain the Room Correction On/Off selection, while the installation set-up procedure will be moved to its own Installation and Set-Up sub-menu along with the Channel Levels sub-menu.

In the Installation and Set-Up sub-menu there will be an added feature for automatic level setup and phase of the individual drivers, as well as a feature to send a short burst-sound to every individual driver to make the set-up procedure easier. This will automatically compensate for inverted amplifier polarity and gain differences.

As before, there will be descriptions on the remote pages that explain the functions. The status updates during the room correction and other processes will be improved in the new release, as well as some other small improvements to the remote pages to enhance the overall user experience. A balance control will also be added in the next update. It requires a number of programming steps for all outputs to be affected properly.

As for users with other speakers, the Wavelet's price when sold separately will be \$4950. The price for a consumer to trade-in the original Wavelaunch processors supplied with Aeris and Whisper XD will be \$3450. The formal release of the Wavelet configured with an algorithm for the Aeris algorithm was November 1, 2015.

## Summing Up

As I said in the introduction to this review, this is one of the best speaker *systems* I've heard, and the Wavelet shows great promise for Legacy's other speakers and for the future of digital room correction and processing. It is worth the trip to hear a demonstration, even if its price makes it a dream for most audiophiles.

The Legacy V does not make every other speaker obsolete or make the kind of sonic differences to die for. No unit with as much processing as the Wavelet can be totally neutral, although it is very good in this respect, and no given piece of equipment in the audio chain is ever truly neutral. Like every other preamp and DAC, there is slight coloration here although it consists of a very minor touch of added midrange warmth, which is musically realistic.

The Legacy is, however, one of those rare new approaches to high-end audio that is so good that it almost compels serious audiophiles to audition it. It does have some truly great competition from speakers without any of the features of the Wavelet—and you should know this. But damn, the Legacy V is really good! **tas**