



**PRO SOUND  
COMES HOME™**

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**LS SERIES**  
TECHNICAL WHITE PAPER



## INTRODUCTION

THE LS SERIES. AN ADVANCED NEW EXPRESSION OF THE MOST ADVANCED JBL® TECHNOLOGIES

New high-performance LS Series loudspeakers share a design philosophy and a Bi-Radial® horn/compression driver configuration with the widely acclaimed JBL Project K2® and Project Array™ speakers, as well as with Project Everest DD66000 – the most lifelike musical instrument JBL engineers have ever created.

In the high frequencies, LS Series speakers employ a constant-directivity HF compression driver and UHF ring tweeter in a unique computer-optimized baffle that suppresses phase interference and signal loss. The realism of low-frequency sound is heightened with high-performance, dual pulp-cone woofers in a staggered network design for exceptionally rich bass response. Working together, these technologies ensure that LS Series speakers render “end-of-the-world” action sequences and delicate, otherworldly musical passages with equal clarity and accuracy.

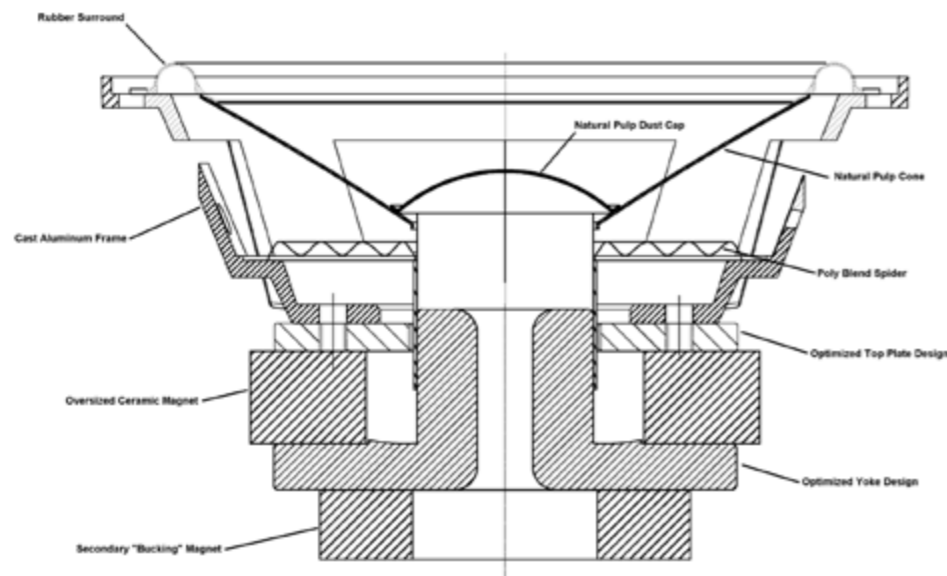


Figure 1 – LS80 woofer cross-sectional diagram.

## DEFINITIONS

### THERMAL COMPRESSION

Loudspeakers generate heat during operation. Heat has the side effect of changing the performance of a loudspeaker, because the material properties of the loudspeaker's component parts are changing. For example, the voice coil of a transducer increases in electrical resistance as it gets hotter, causing a reduction of voltage sensitivity – the level of acoustic energy the transducer produces for a given voltage. Thermal compression is also known as transient compression or power compression, depending on the timescale of the property changes. Dynamic compression is caused by instantaneous changes in the temperature of the voice coil because of transients present in the signal (such as a bass drum hit). The larger the voice coil, the better it can absorb transient thermal loads with less heating. Power compression happens over a longer timescale, caused by the average power being handled by the transducer. Power compression is a function of the ability of the transducer to pull heat away from the voice coil and transfer it to the ambient surroundings. A larger motor structure with better ventilation helps to accomplish this.

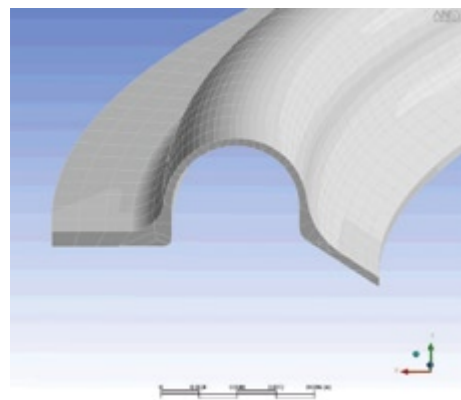


Figure 2 – LS80 woofer surround: A cutaway view shows the individual “elements” used by finite element analysis.

### DIRECTIVITY

Directivity – or more specifically, the directivity index – is the difference between direct sound and the sound radiated into the rest of a listening environment. The indirect sound can further be broken down into that sound which returns to the listener as a “first reflection” from nearby boundaries and that which is integrated into the reverberant sound power. Many people are aware of the importance of having a balanced frequency response, but unaware of how critical it is to have a smooth directivity-index response, both for first reflections and sound power. A smooth directivity-index response ensures that the sound that a listener hears from first reflections or reverberant sound is similar in timbre to the direct sound. This gives the sound a more natural and accurate character. In fact, loudspeakers with abrupt directivity-index response discontinuities can sound colored, even if the on-axis response is ideal.

### FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) is a computer analysis technique, using the finite element method to break large complex systems into small pieces (or elements). In the real world, many (if not most) systems are so complex that an analytical solution is not practical or even possible. A simple formula will not give an answer with an acceptable level of accuracy. This is the case with many transducer components, including the suspension system and the magnetic circuit of the motor. But by breaking the complex system into its component parts, the system becomes predictable, because each element is solvable. The system solution is simply the combination of the element solutions.

## LOW-FREQUENCY TRANSDUCER

### NATURAL PULP CONE

The optimum loudspeaker diaphragm is both lightweight and stiff. The natural-pulp (paper) material selected for JBL LS Series cones has both of these attributes, as well as very high internal damping, which reduces the acoustic effect of internal cone resonances and breakup.

### OVERSIZED VOICE COIL WITH KAPTON® FORMER

A larger diameter voice coil allows for increased motor strength and heat transfer. This is because more copper can be put into the magnetic gap, where the motor force is produced, and the larger surface area is able to radiate more heat away from the coil. This in turn produces more confident transient response with lower thermal compression and distortion.

### MOTOR GEOMETRY, OPTIMIZED FOR MAXIMUM STRENGTH AND FIELD SYMMETRY

The motor of a loudspeaker should produce symmetrical force in order to reduce distortion. In other words, the motor should produce the same force, whether the diaphragm and voice coil are in front of or behind the rest position. The motor geometry of the low-frequency transducers for JBL LS Series loudspeakers has been optimized, using magnetic finite element analysis to maximize both the amount of force produced by the motor and the force symmetry.

## SUSPENSION GEOMETRY, OPTIMIZED FOR LINEARITY AND SYMMETRY

Just as motor force symmetry reduces distortion, restoring force symmetry of the transducer's suspension system has the same effect. This is why finite element analysis was also used to optimize the critical components of the suspension, including the surround and spider.

### OVERSIZED POLE VENT ELIMINATES NOISE FROM AIR TRAPPED UNDER DUST CAP

As the diaphragm of a transducer moves with respect to the motor structure, the pressure under the dust cap can fluctuate greatly. Unless adequate ventilation is provided to this area, the resulting pressure differences can cause air to flow rapidly through whatever openings are available, such as the magnetic gap around the voice coil. The rapid flow of air around obstructions can cause excessive noise as the diaphragm moves. The low-frequency transducers for JBL LS Series loudspeakers have been designed with oversized pole vents to prevent large pressure differences under the dust cap and prevent excessive airflow noise.

### CAST-ALUMINUM FRAME

The transducer frame is the mechanical foundation upon which the other transducer components are built. Like the foundation of a building, it should be solid and stable. It should keep all the parts anchored to it from moving, relative to one another. Cast aluminum is ideal for this application, since it is very strong and stiff.

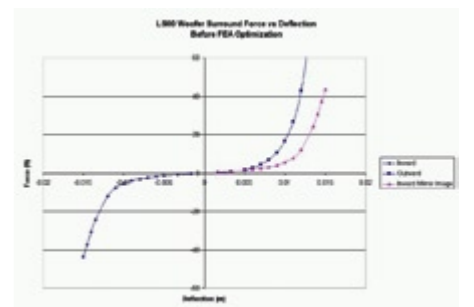


Figure 3 – Predicted force vs. deflection curve for LS80 surround before optimization: The vertical scale shows the restoring force in newtons, while the horizontal scale shows the excursion in meters. In the upper right quadrant, the disparity between inward and outward restoring force can be seen.

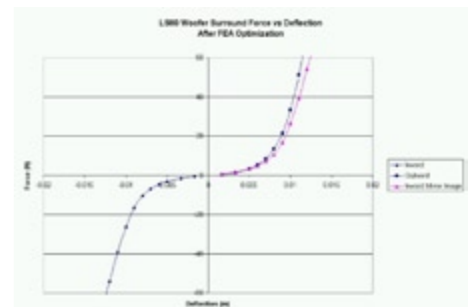


Figure 4 – Predicted force vs. deflection curve for LS80 surround after optimization: The symmetry between inward and outward restoring force has been substantially improved.



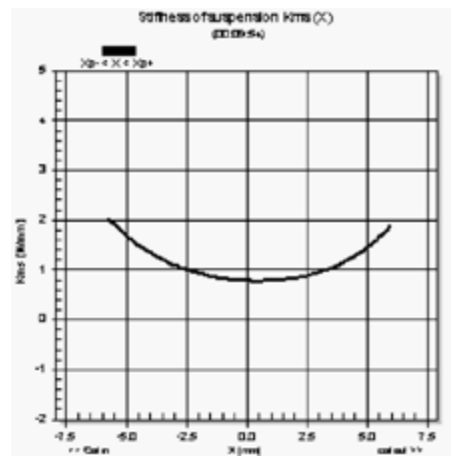


Figure 5 – Confirmation of suspension symmetry optimization can be seen in actual measurement of transducer. In this graph, the horizontal scale is excursion in millimeters, and the vertical scale is stiffness in newtons per millimeter.

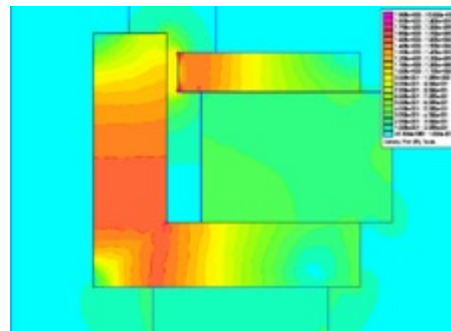


Figure 6 – Magnetic finite element analysis was used to optimize design for motor strength and force symmetry.

## HIGH-FREQUENCY COMPRESSION TRANSDUCER

### POWERFUL NEODYMIUM-IRON-BORON MAGNET

Neodymium-iron-boron magnets have approximately 10 times the energy of ceramic magnets. This extra energy allows for a more efficient transfer of the electrical signal into sound output. Less of the electrical energy is lost as heat, and this reduces thermal compression.

### 50MM TITANIUM DIAPHRAGM WITH DIAMOND SURROUND AND VISCO-ELASTIC DAMPING

The compression driver diaphragm utilizes a pure-titanium diaphragm. This material is very stiff and durable, yet lightweight. The diaphragm also features a visco-elastic damping polymer applied to the rear surface. The polymer treatment reduces unwanted resonances and creates a smoother frequency response.

### ALUMINUM EDGE-WOUND VOICE COIL ON KAPTON BOBBIN WITH FERROFLUID COOLING

In order to extract the maximum performance from the motor, it is important to get as much of the voice coil into the magnetic gap as possible. An edge-wound voice coil helps to achieve this with a rectangular wire profile that minimizes the space between windings. It also allows a closer thermal coupling to the motor structure, to move heat away from the voice coil, allowing for higher power handling and lower thermal compression. The addition of ferrofluid enhances this heat transfer even further.



## ULTRAHIGH-FREQUENCY TRANSDUCER

### DURABLE, YET LIGHTWEIGHT 19MM POLYIMIDE DIAPHRAGM

The low-moving mass of the diaphragm allows the transducer to provide exceptional efficiency for a direct-radiating ultrahigh-frequency driver. A neodymium-iron-boron magnet is also utilized to help in this regard. Less power is required to produce a given level of sound output and, as a result, thermal compression is reduced, while dynamic response is enhanced. In addition, the low-moving mass allows a frequency response past 40kHz.

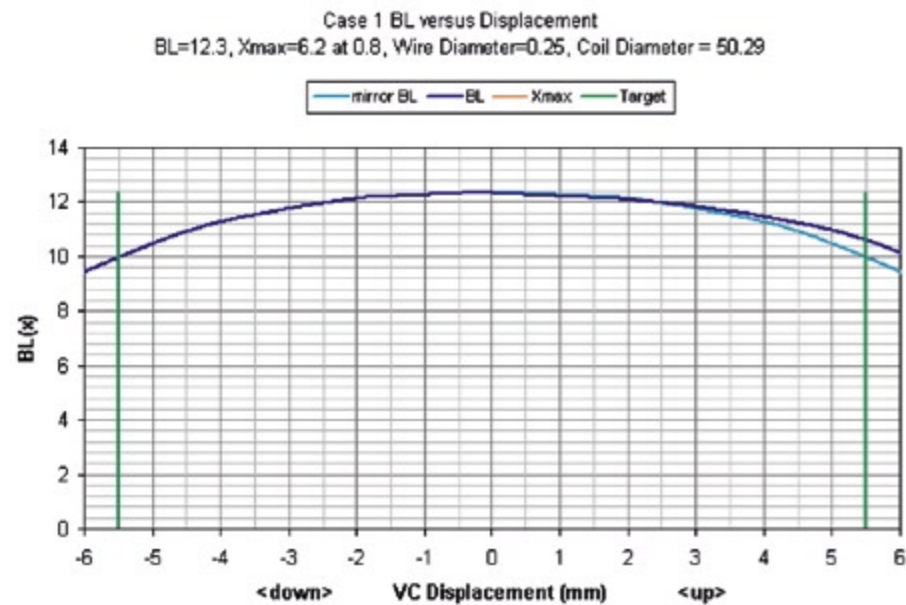


Figure 7 – Magnetic finite element analysis prediction of motor force symmetry: Design was optimized for greatest symmetry at small to moderate excursion.

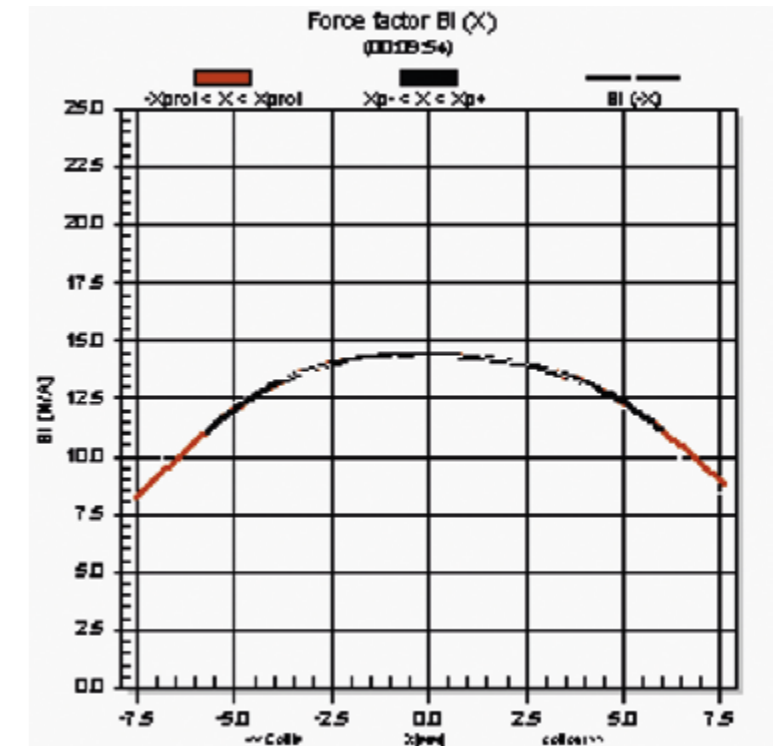
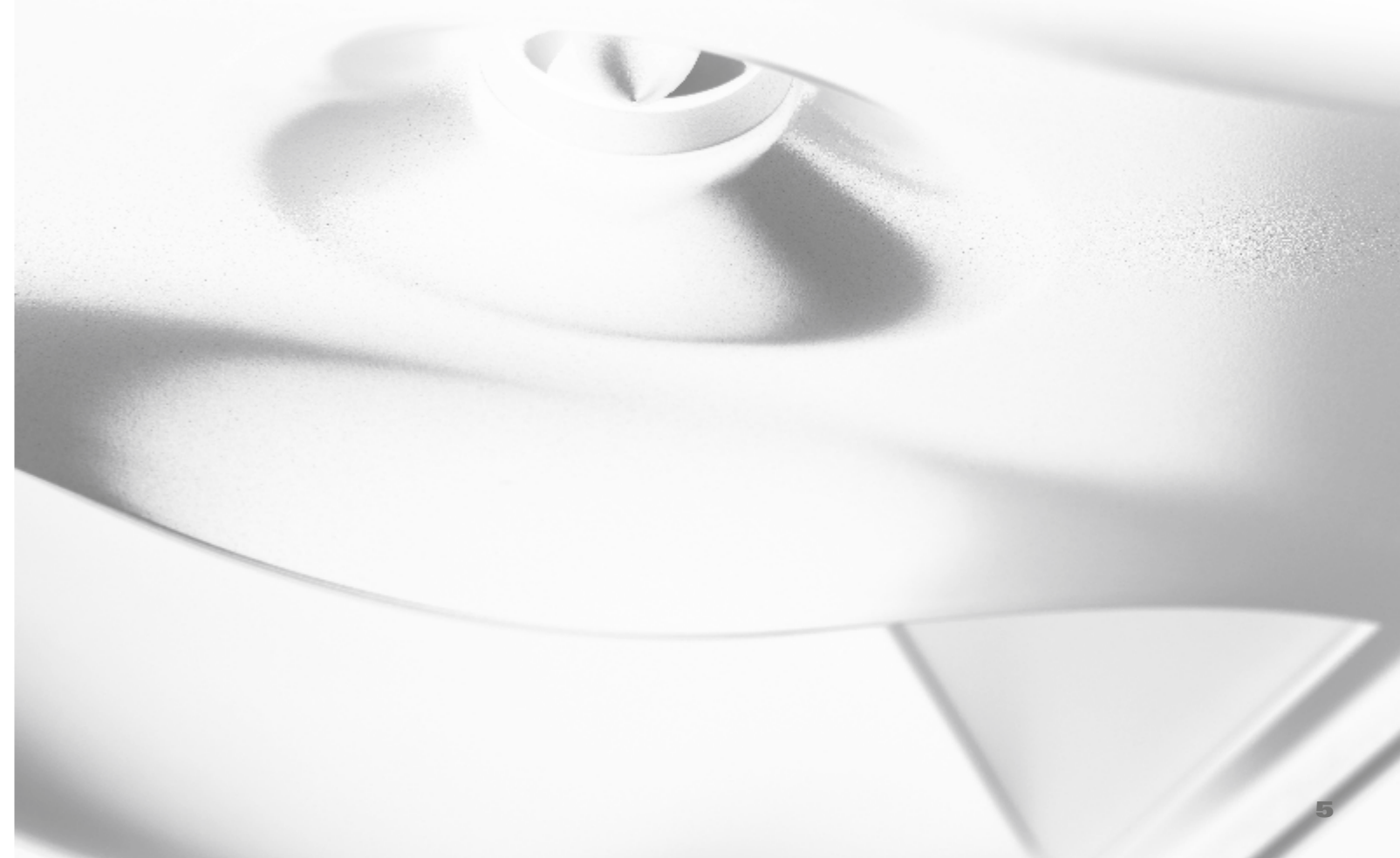


Figure 8 – Confirmation of motor design optimization can be seen in actual measurement of transducer.



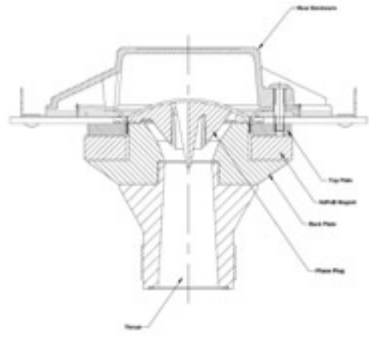


Figure 9 – 176Nd cross-sectional diagram



### HORN DESIGN

#### COMPUTER-OPTIMIZED EXPONENTIAL HORN, WITH REDUCED INTERNAL DIFFRACTION

Many horn designs are based on the assumption that sound waves remain planar as they travel down the horn (they don't). With this assumption, horn profile is calculated based on the cross-sectional area of the horn, leading to an error in horn expansion, which results in reduced loading. The horn for the JBL LS Series was designed without this erroneous assumption. Wave front area was calculated directly, using numerical solution techniques, and the horn profile was set accordingly. The result is a true exponential horn profile that maximizes horn loading for its size. More loading equals higher efficiency and less power needed for a given sound level. As a result, music sounds more "effortless" and open. Transient response is maximized and microdynamic nuances are revealed. The horn for the LS Series was also designed to have reduced internal diffraction, allowing the horn to sound spectrally balanced and neutral, without inducing colorations. Directivity of the horn was designed to complement the overall system design. Constant directivity on a horizontal plane produces a consistent sound level across the listening area, while a smooth directivity transition in the vertical plane assists in the integration of multiple transducers.

### CROSSOVER NETWORK DESIGN

#### 3-1/2-WAY NETWORK DESIGN, UTILIZING HIGH-QUALITY COMPONENTS

In order to minimize perceived colorations, sound reflections from walls should have a spectral content that is similar to the direct sound. This requires a smooth directivity transition between each of the transducers used, with no abrupt discontinuities. For JBL LS60 and LS80, a 3-1/2-way design is used to fade the bottom woofer out, allowing the top woofer alone to cross over to the compression driver. This matches the directivity at the crossover point and creates a smooth transition. All models utilize high-quality components, including polypropylene capacitors and air core inductors, where appropriate, for increased sound quality.

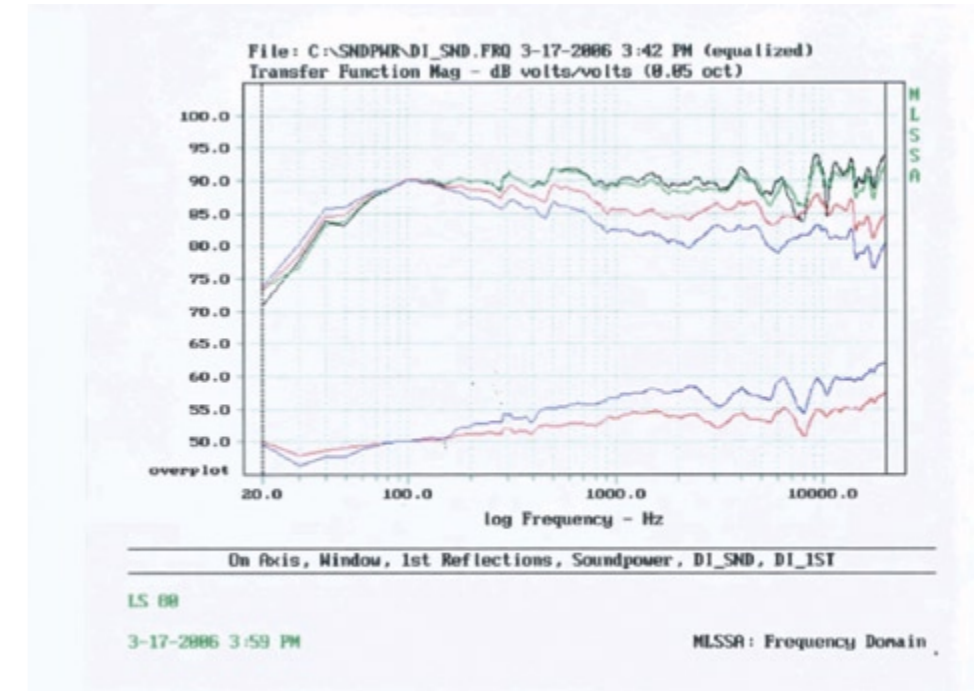


Figure 11 – LS80 system measurement: The black curve is the on-axis response and the green curve is an average of measurements at a small angular displacement from the axis. This is also called the "listening window", and is what is used as direct sound for directivity index calculations. The upper red and blue curves are the first reflections and sound power, respectively. The lower red and blue curves are the directivity indices for the corresponding first reflection and sound power curves.

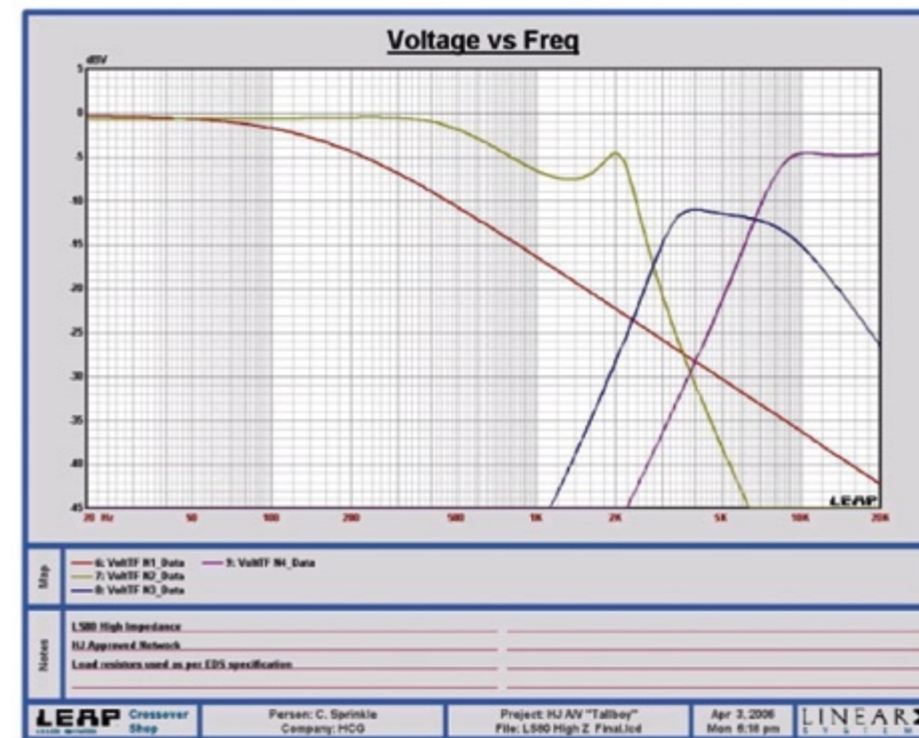


Figure 10 – LS80 system network voltage transfer function: The staggered low frequency network design allows the system to accomplish a smooth directivity transition between the low frequency transducers and the compression driver / horn.