Finding the Prototype for Stereo Loudspeakers

The following presentation slides from the AES 51st Conference on Loudspeakers and Headphones summarize my activities and observations for the design of loudspeakers and stereo perception. I conclude with a loudspeaker concept and a loudspeaker-room-listener configuration for creating a truly convincing auditory illusion in the listener’s mind, where loudspeakers and listening room disappear from auditory attention. Here the recording venue, the spatial rendering of the instruments and their sounds dominate the perceived auditory scene.

My interest in loudspeakers developed out of a shared hobby with other engineers at Hewlett Packard Co. in California. After work we designed and built our personal Hi-Fi systems, having free access to tools and supplies. Being in R&D for the design of RF & Microwave Test Equipment and familiar with electro-magnetic wave propagation issues, we looked at loudspeakers as broadband antennas covering 20 MHz to 20 GHz, which is the same wavelength range as 20 Hz to 20 kHz in acoustics and with similar physical size related problems.

The radiation pattern of an EM-antenna is critical for its application. As it turns out the radiation pattern or polar response of a loudspeaker is a highly important contributor to auditory perception and pattern recognition in reverberant spaces.

Finding the Prototype for Stereo Loudspeakers

Siegfried Linkwitz

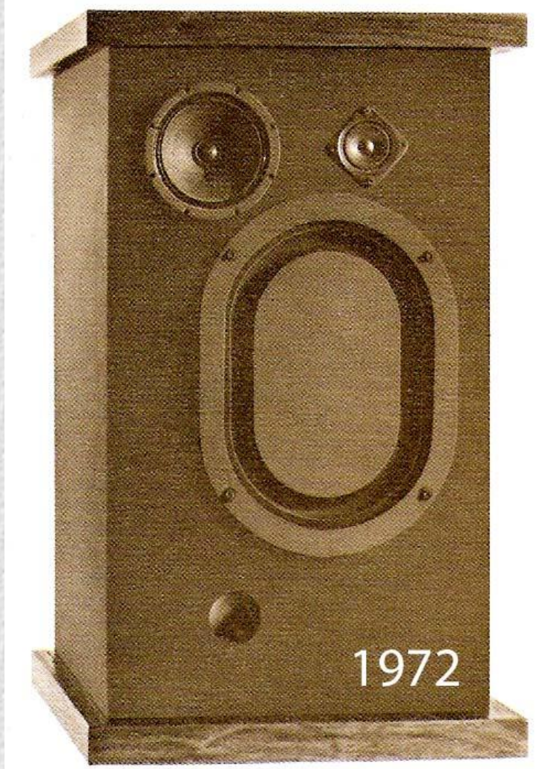
Understanding Loudspeaker Designs

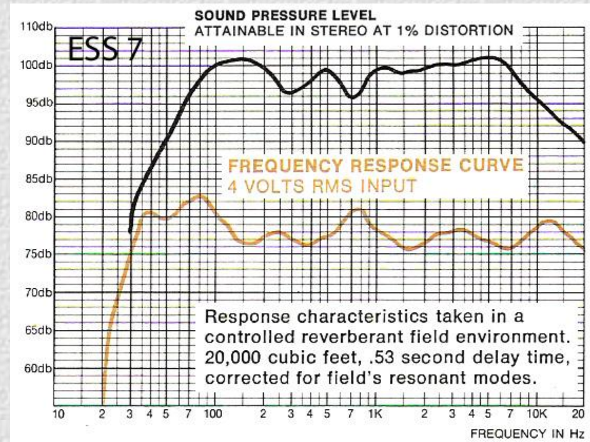
Why?

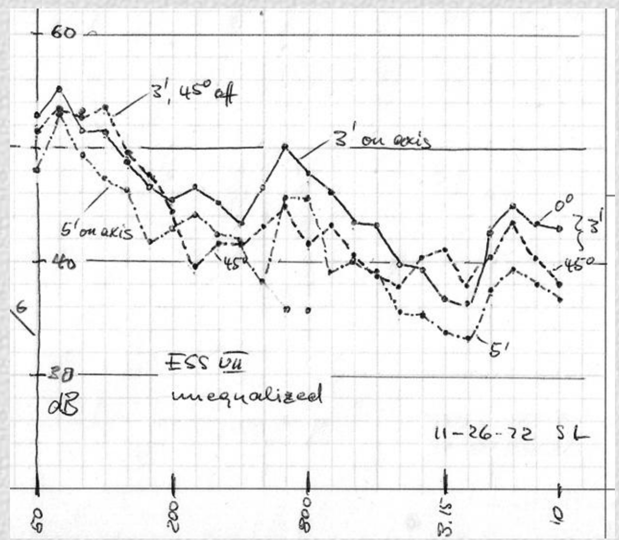
- Two-way systems
- Acoustic suspension woofers
- Marginal tweeters
- Driver layout?
- Frequency response?

Understanding Loudspeaker Designs

The ESS SEVEN with grill cloth removed showing its unique flat piston foam woofer, linear, narrow bandwidth midrange and low mass tweeter. The critically sized, damped port relieves air pressure against the rear of the woofer to allow linear excursion into exceptionally deep bass regions.







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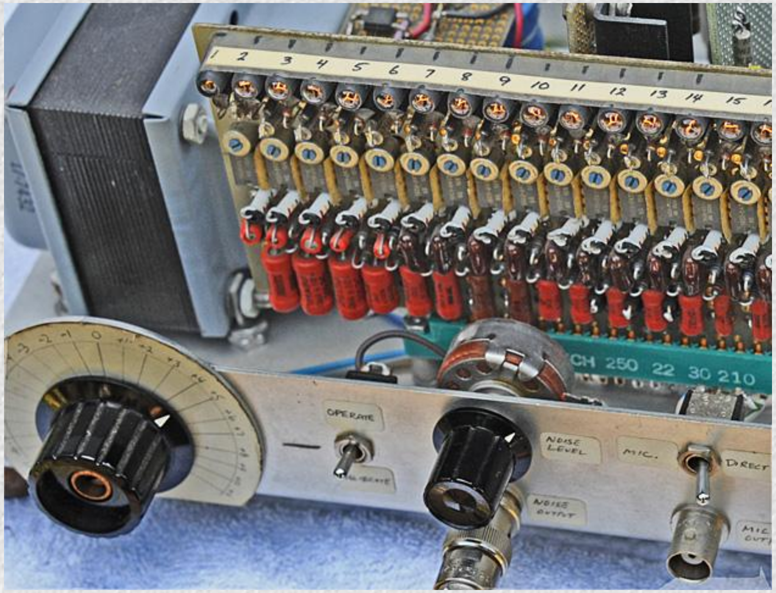
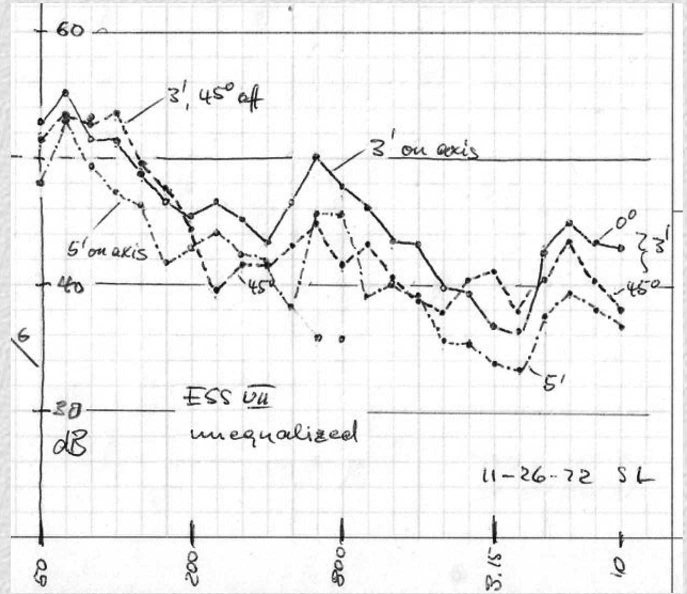
Making Loudspeaker Measurements

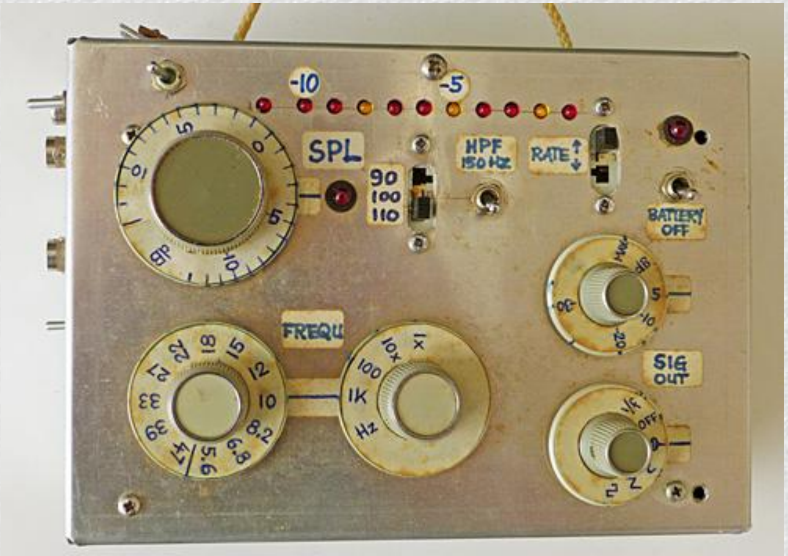


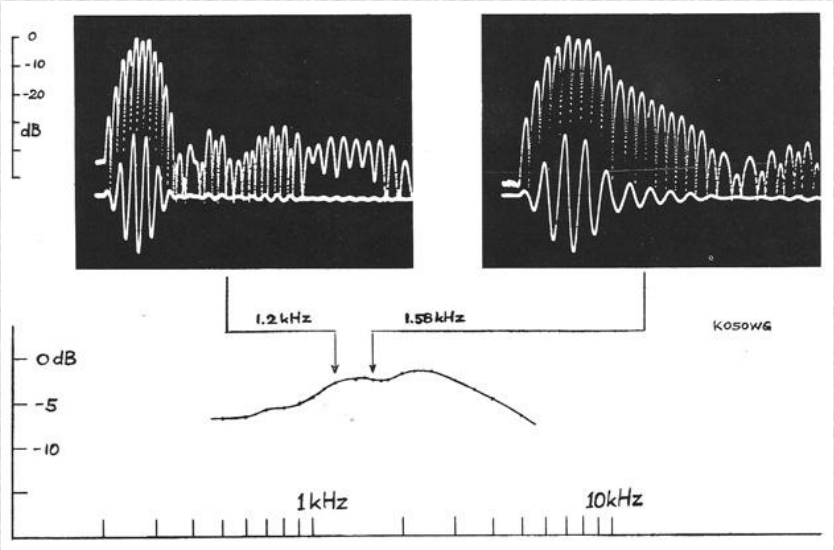


Russ Riley
Lyman Miller

- 22 2-pole bandpass filters, 50Hz to 10 kHz
- 22 light bulbs as RMS detectors
- Calibrated input gain adjustment
- Electret microphone capsule
- Pink noise from microwave point contact diode

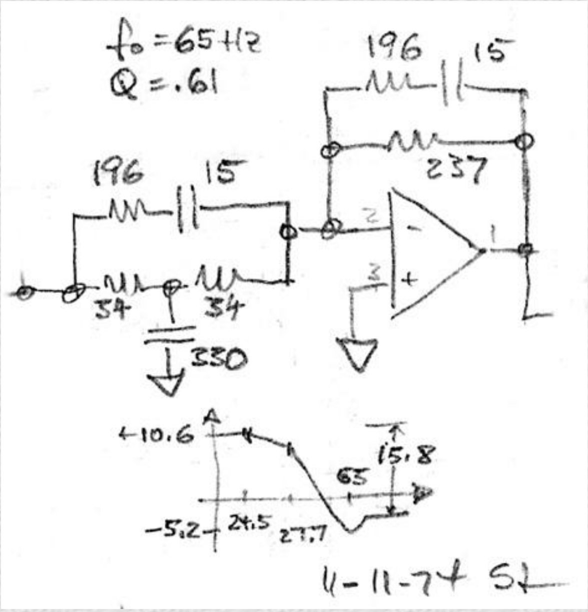
Sound & Vibration Measurements with Shaped Tone Bursts





- 5-cycle, cosine-envelope bursts from 5.6 Hz to 47 kHz
- Two bursts/second
- Fast peak detector
- Calibrated gain in dB linear steps
- Linear and log oscilloscope display
- Phono cartridge for vibration tests

Improving Commercial Products

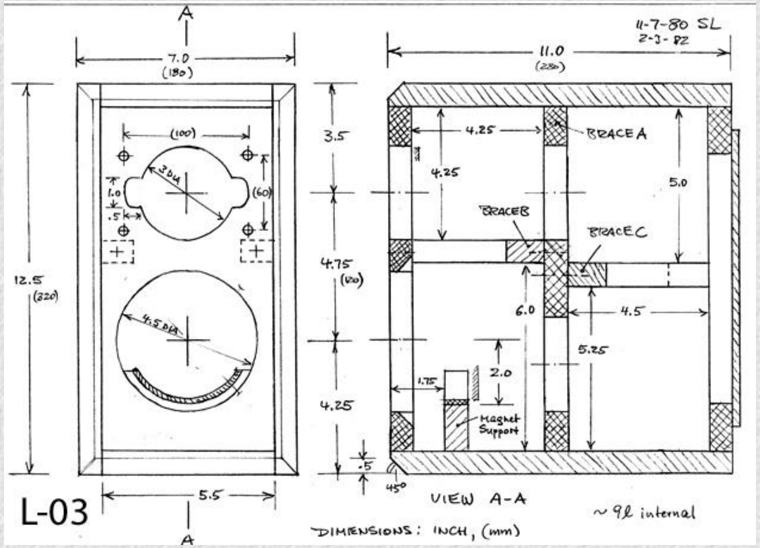


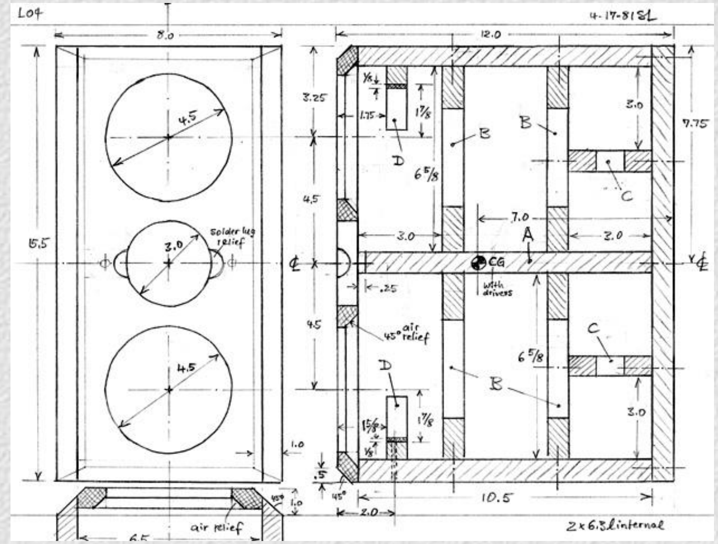
- Small boxes for reduced panel radiation
- Low frequency extension by equalization

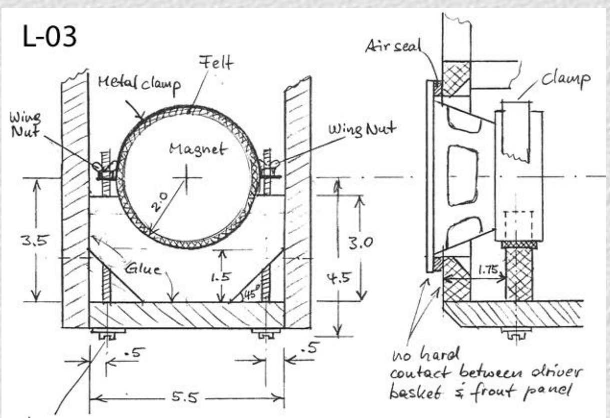
My Box-Speaker Designs

- Free-hanging satellites
- Summed-signal woofer (stops TT vertical rumble)
- Amplifier for each driver
- Line-level EQ & XO

My Box-Speaker Designs



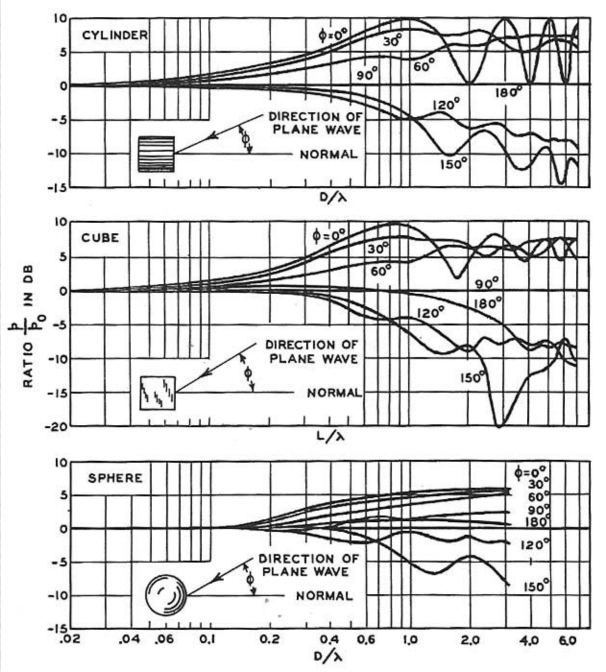


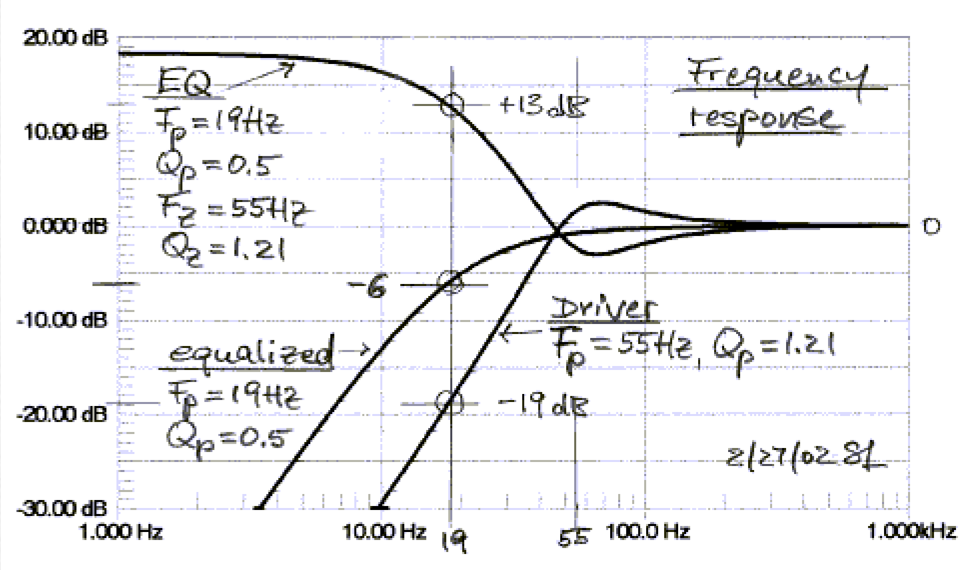


- Vertical driver layout, symmetry, lobing
- Narrow baffle, wide dispersion, diffraction
- Bracing to increase panel stiffness
- Clamping the magnet to stop high Q resonance of stamped metal basket and magnet

My Design Procedure - 1

- Measure baffle mounted drivers in free-field
- Equalize each driver beyond the intended crossover frequency
- Equalize low end with biquad (LT)





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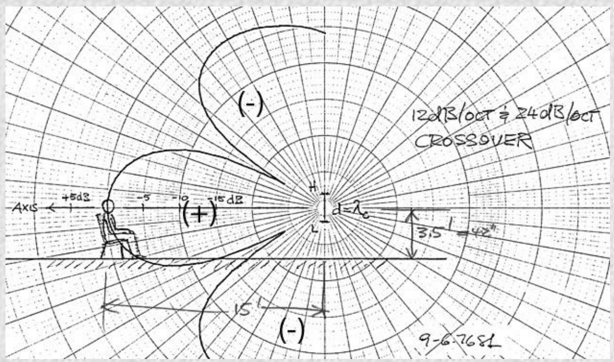
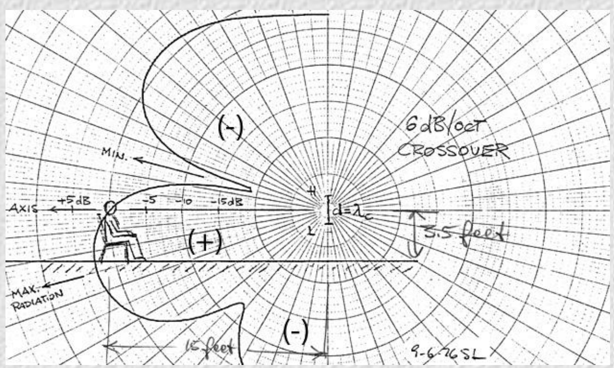
My Design Procedure - 2

- Add in-phase electrical crossover filters (LR4)
- Compensate acoustic offset between drivers with allpass filter
- Adjust overall response in free-field
- Listen critically to single speaker

LR4



B1



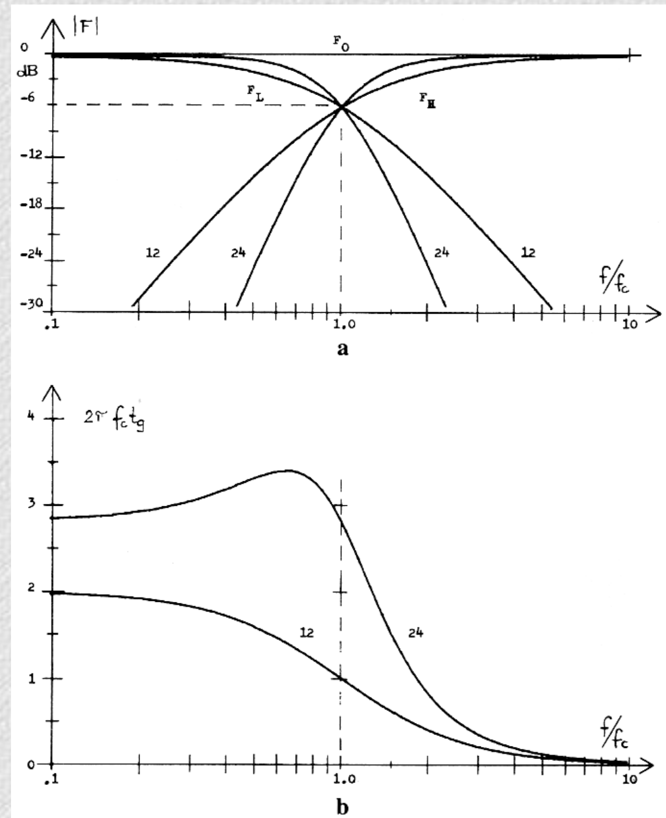


Fig. 6. Optimum crossover function response. **a.** Amplitude response. **b.** Group delay response.

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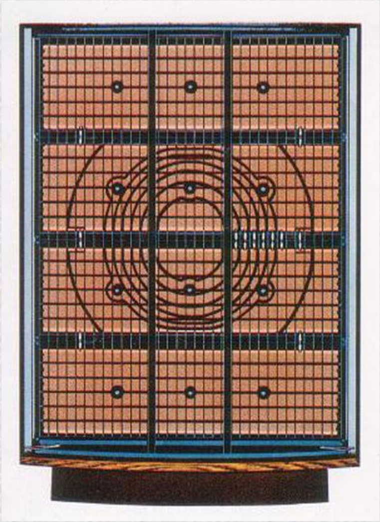
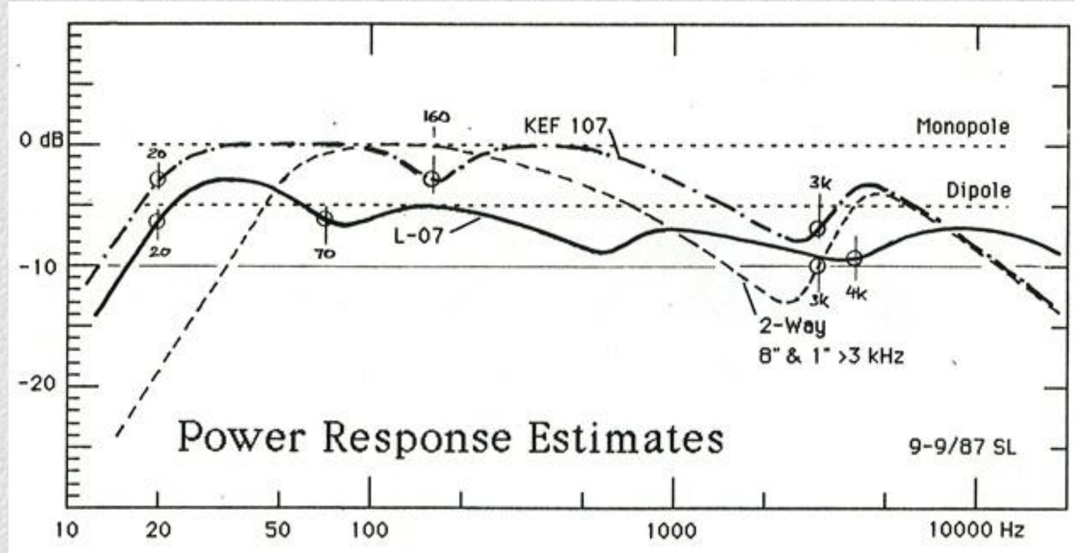
Dipole Loudspeaker Inspirations



QUAD ESL-63

• 2.5 m dipole column for PA
• 12 drivers,
• reduced to center 4 at high frequencies

My Dipole Loudspeaker Designs



- 4-way System
- 3-way Dipole
  LM-UM-T-UM-LM
- 2π-Woofer, L&R summed

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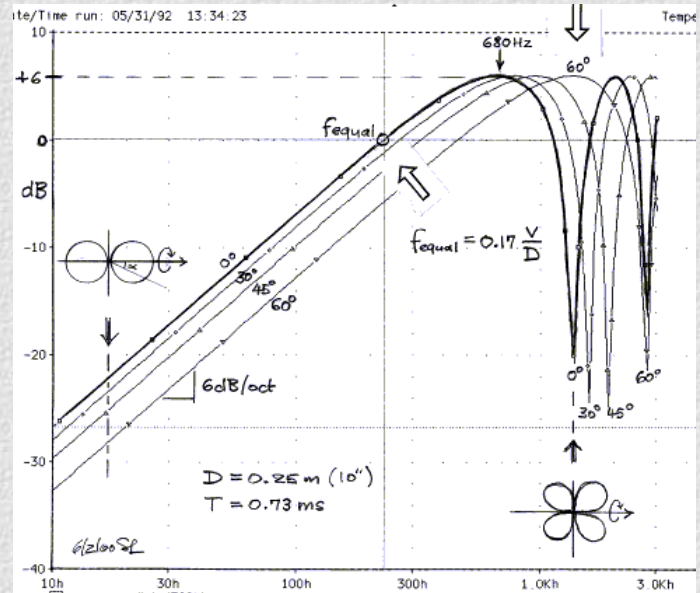
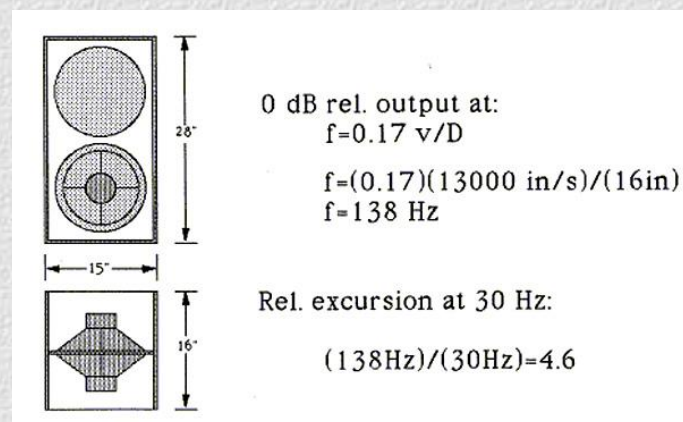
H-frame Dipole Woofer

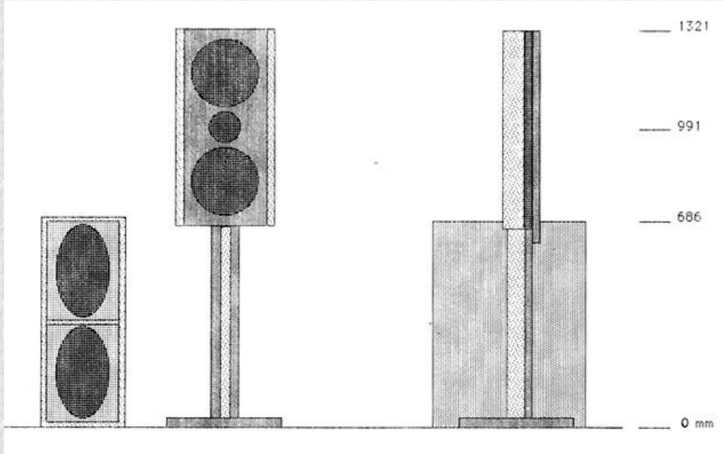
Brian Elliott

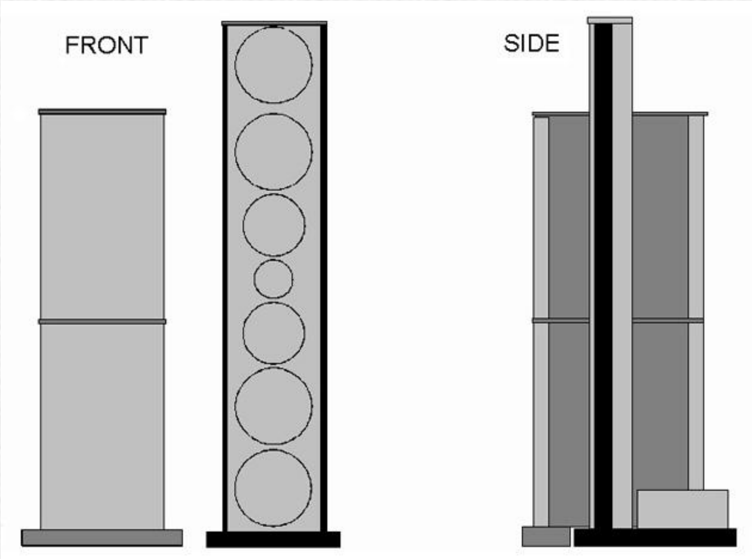




- Compact, symmetrical baffle
- Large excursions
- Reduced even-order distortion

My Dipole Loudspeaker Designs



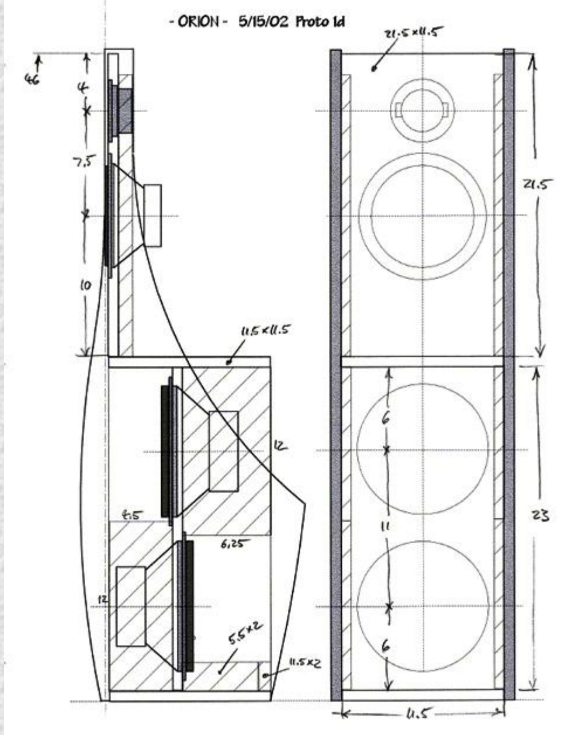


- Audio Artistry - Dvorak
- Audio Artistry - Vivaldi

- Audio Artistry - Beethoven Grand

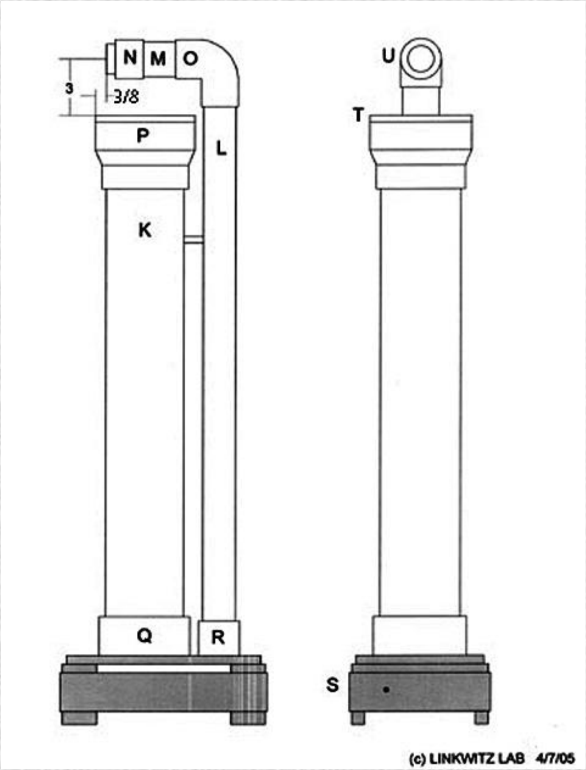
- 2-way active systems with passive LM to UM to Tweeter xo/eq
- Fully active systems

ORION - “dipole”



• Highest performance with acceptance of form

Surprising PLUTO - “monopole”

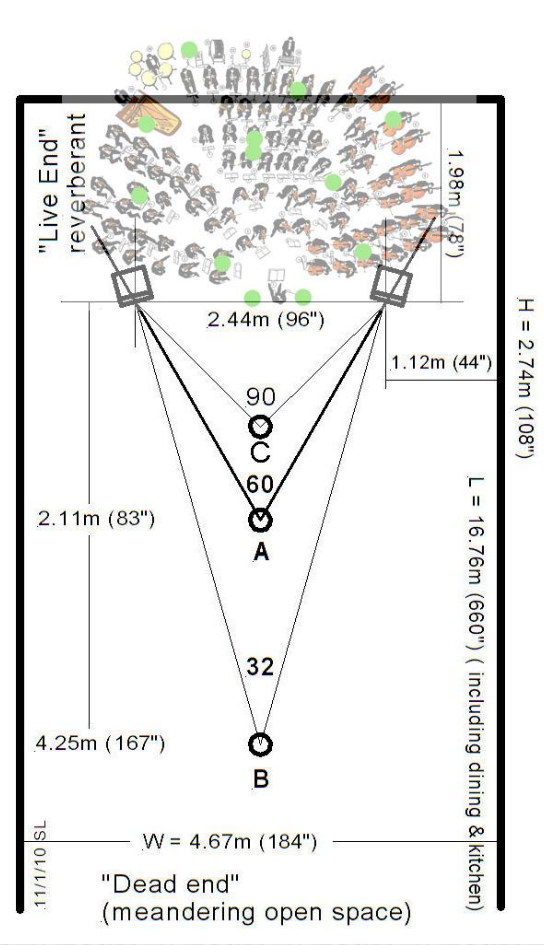


- Minimized diffraction
- Sonic similarity to ORION and differences

ORION - Rear Tweeter

LX521 - dipole

• Full range, acoustically small dipole
• Form Follows Function



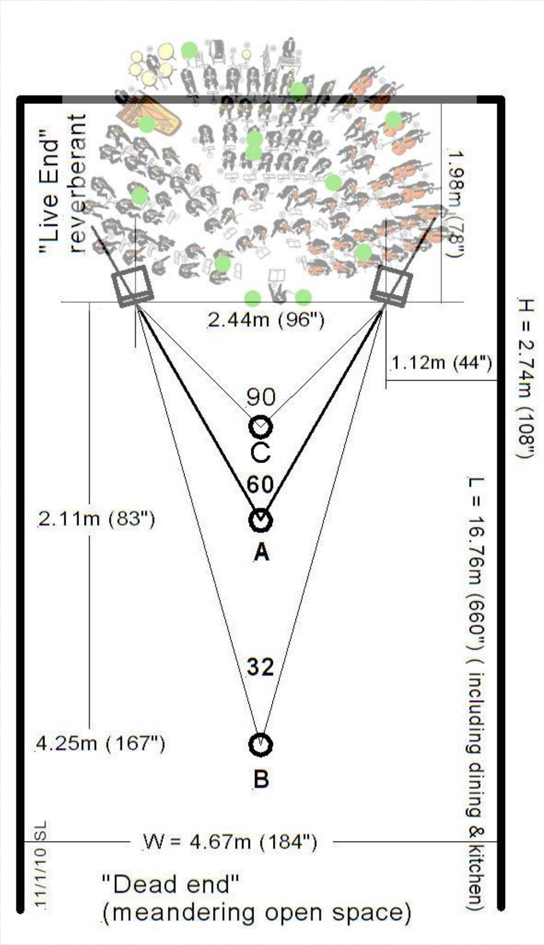
Hearing & Stereo - 1

1) Hearing the direction & distance of a source in a reflective environment is a natural survival mechanism (Head movement, Recognizing the loudspeaker or headphone location & distance)

2) We segregate signal streams and focus attention at will (Cocktail Party Effect, Acoustic Horizon)

3) Hearing stereo is an auditory illusion, which is derived from cues in the loudspeaker and room signal streams, from memory patterns and adaptation to the acoustic environment (Avoid to give misleading cues due to cabinet diffraction, panel and cavity resonances, non-linear distortion and spurious noises)

4) The auditory illusion is perfect when misleading cues have been eliminated and is like a magician's trick (Loudspeakers and room disappear from the auditory scene)



Hearing & Stereo - 2

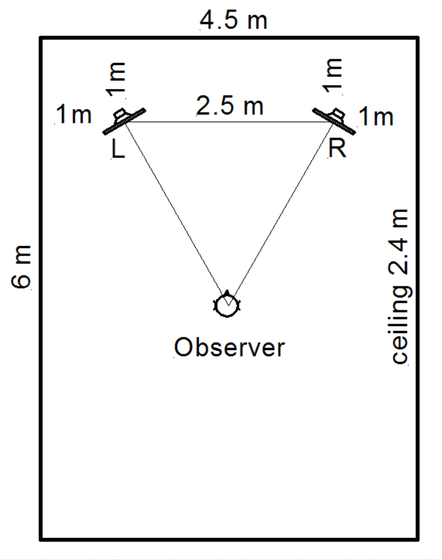
5) The room reflected and reverberated sound must have the same timbre as the direct sound from the speakers to eliminate misleading cues (Constant Directivity loudspeakers)

6) Room reflections must be delayed for segregation from the direct sound streams (>6 ms)

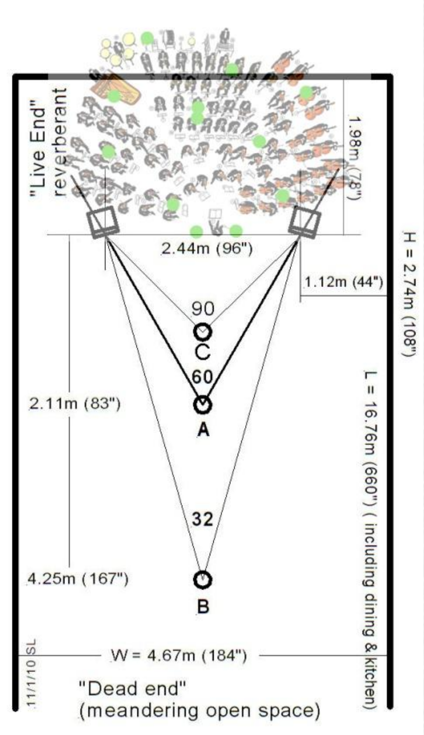
7) Reflections must be symmetrical or suppressed to preserve left-to-right balance of the auditory scene (Symmetry of loudspeaker, listener and room setup)

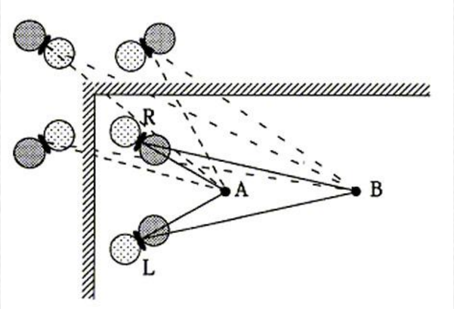
8) The +/-30 degree incident sound must appear spectrally as coming from the front (-3 dB above 1 kHz)

Room Reflections



• >6 ms delay

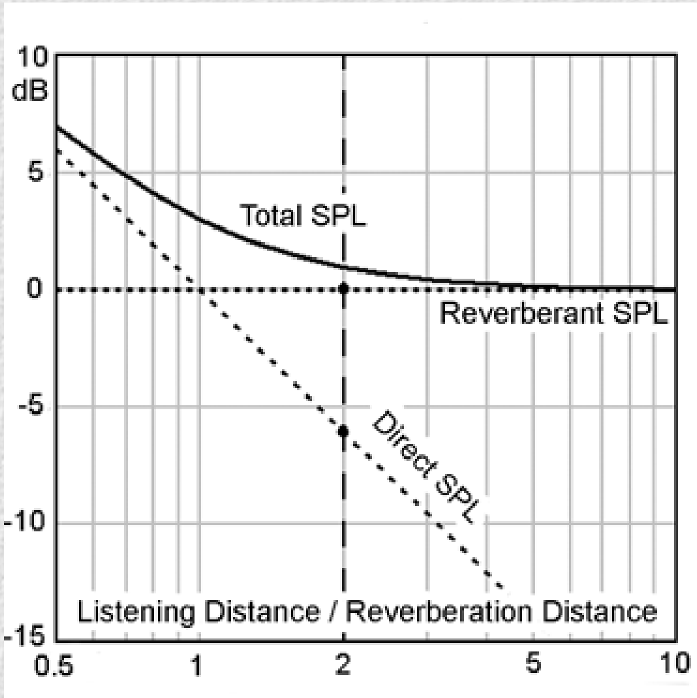


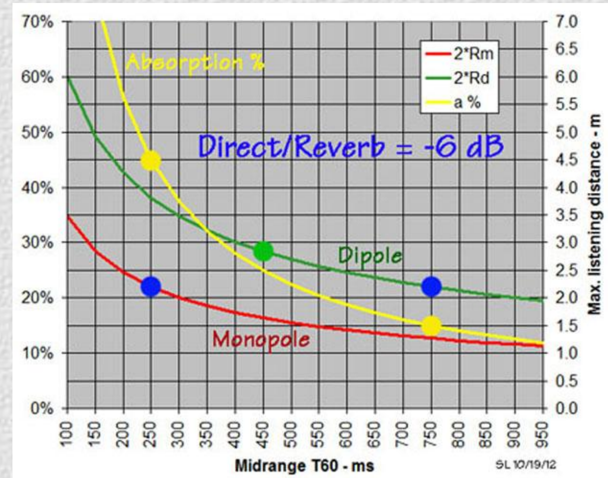


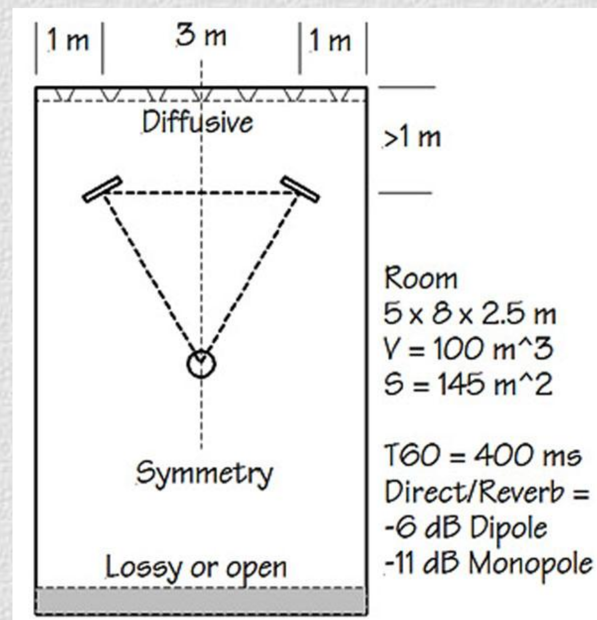
• Toe-in to attenuate first side reflection

• Diffusion behind the speakers
• Attenuation behind the listener

Room Reverberation







- Listening distance:
  <2x Reverberation distance

- RT60 >400 ms

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The Prototype for Stereo Loudspeakers:
An acoustically small dipole

www.magicLX521.com

Try it out !