Welcome

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Test Observations of the Characteristics of the Acoustic Field Generated by High Intensity Loudspeaker Testing

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Background

- Measurements with 36-microphone array in 2011 high intensity loudspeaker demonstration test (known as “DFAT”) indicated that multiple-input-multiple-output (MIMO) control able to somewhat mitigate spatial acoustic gradients seen previously in single-input-single-output control
  - *conducted by Maryland Sound International (MSI), hosted by Johns Hopkins University Applied Physics Laboratory (JHUAPL)*
- Notable exceptions around 95 Hz and 225 Hz, where strong spatial patterns persisted with almost no mitigation
- Theory exists that these frequencies associated with modes of the quasi-cylindrical array of loudspeaker cabinets and floor
- March 2013 demonstration test (conducted by MSI, hosted by JHUAPL) gave opportunity for additional measurements
  - *Determine presence and nature of standing waves*
  - *Observe influence of spacecraft simulator on acoustic field spatial characteristics*
  - *Similar test configuration as 2011, same 36-microphone array configuration*

Overview

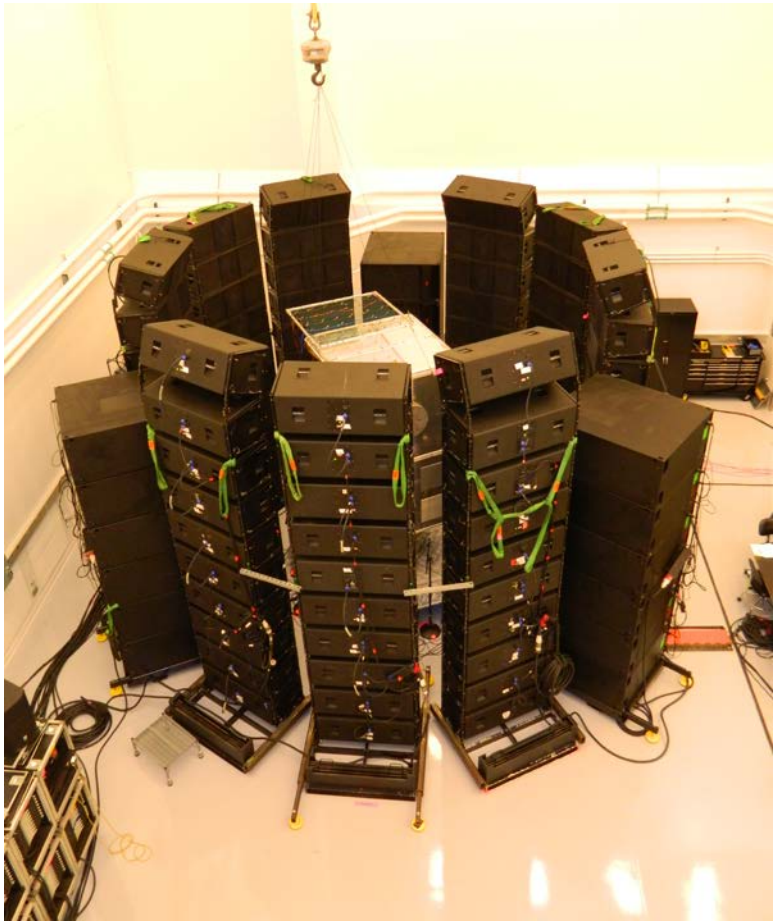
- This presentation summarizes an initial review of data measured with the 36-microphone array
  - *Only PSD spectral data available for this review*
  - *Analysis of time history data to follow*

- Look for evidence of standing waves
  - *Particular focus on spectral peaks at 88 Hz and 216 Hz seen in MIMO controlled run*
    - Similar in nature to 95 Hz and 225 Hz peaks seen in 2011 test

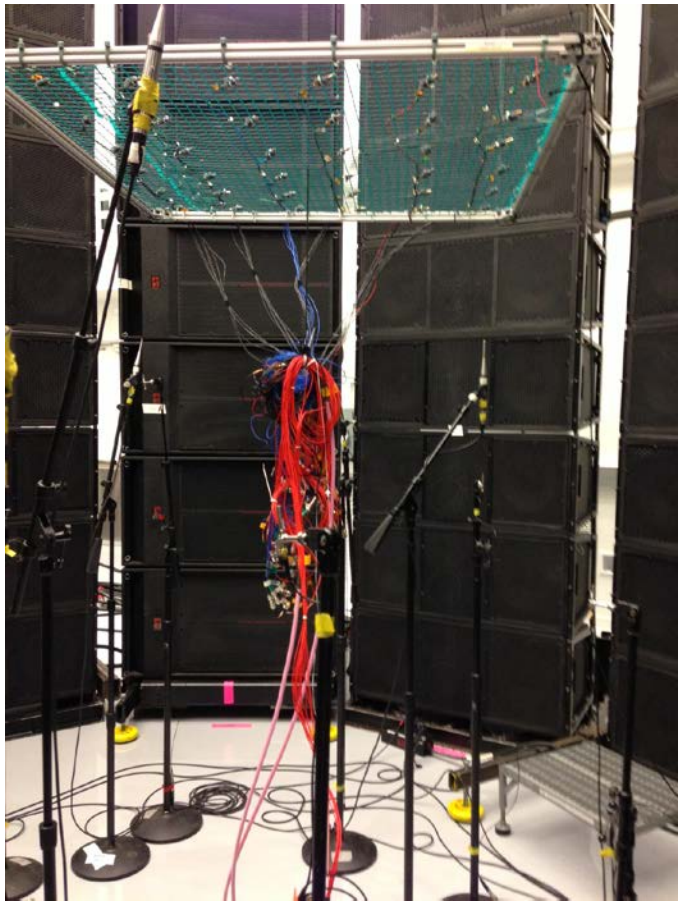
- Observe relative influence of presence of SC simulator on MIMO-controlled acoustic test field

Test Configuration

Speaker array shown with SC Simulator

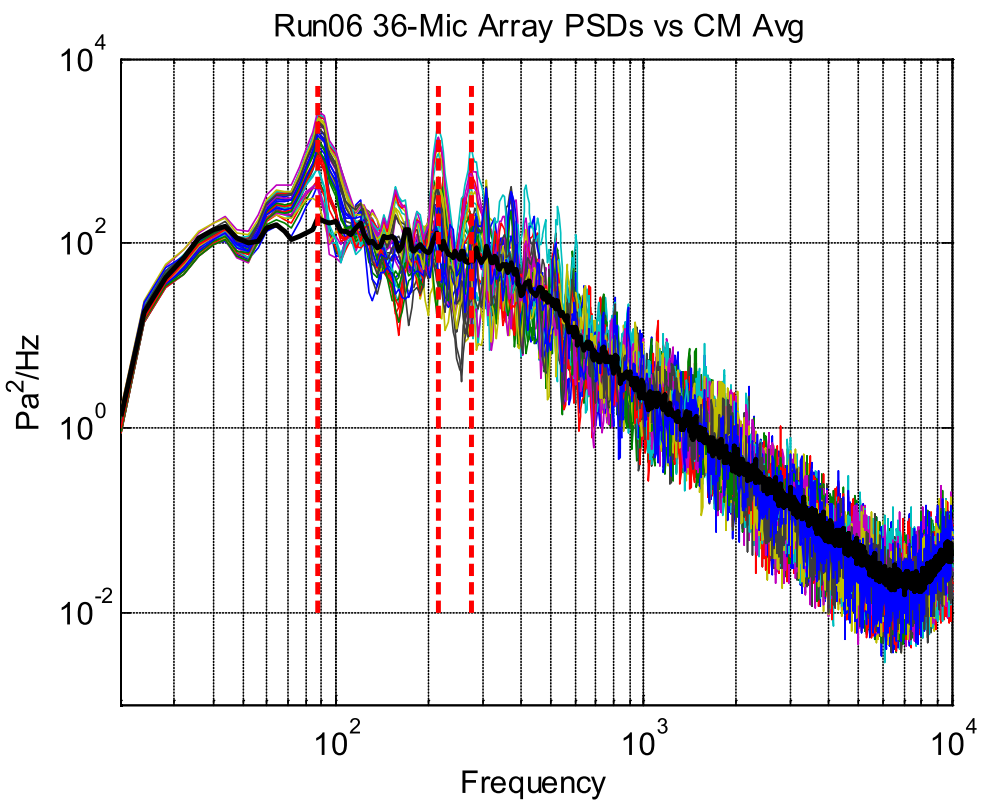


36-microphone array



Photos courtesy of Johns Hopkins University Applied Physics Laboratory

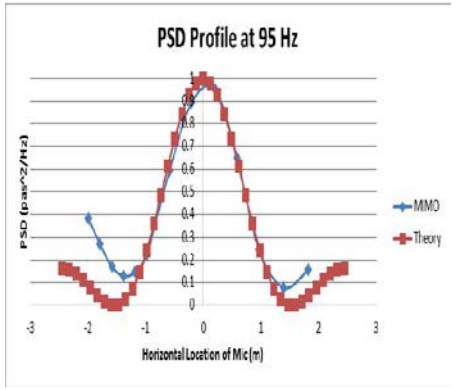
MIMO Control: Empty Test Space – Horizontal Mic Array

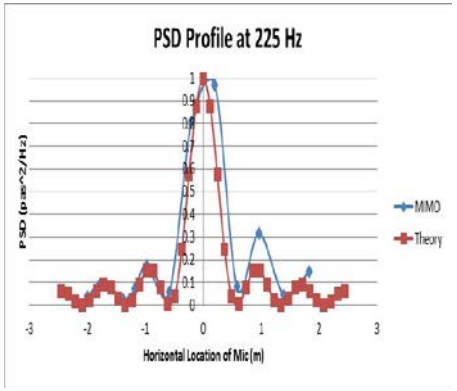


- Frequency slices of interest: 88 Hz, 216 Hz, 276 Hz
  - *88 Hz and 216 Hz appear to coincide with 92 Hz and 229 Hz features noted in 2011 testing*
  - *276 Hz another value of interest*

Single Source Excitation

- Premise if standing waves present (vs. wave interference) respective modes should be excited even with a single internal source
  - *Mode shape dependent on structural boundary conditions – speaker cabinets and floor*
- Look for cylindrical patterns associated with standing waves due to boundary conditions created by loudspeaker cabinet array and floor
  - *Radial modes*
    - *88 Hz theoretical; 95 Hz measured**
    - *239 Hz theoretical; 225 Hz measured**
- Generate pink noise through selected single speaker with open loop control
  - *Excitation of mode should be independent of internal source location*

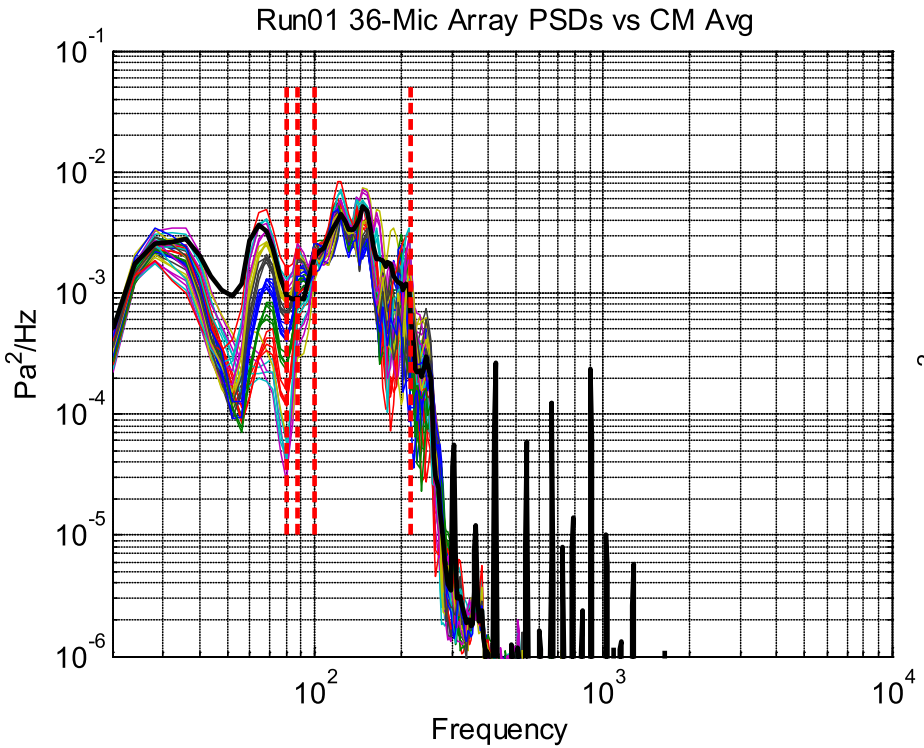




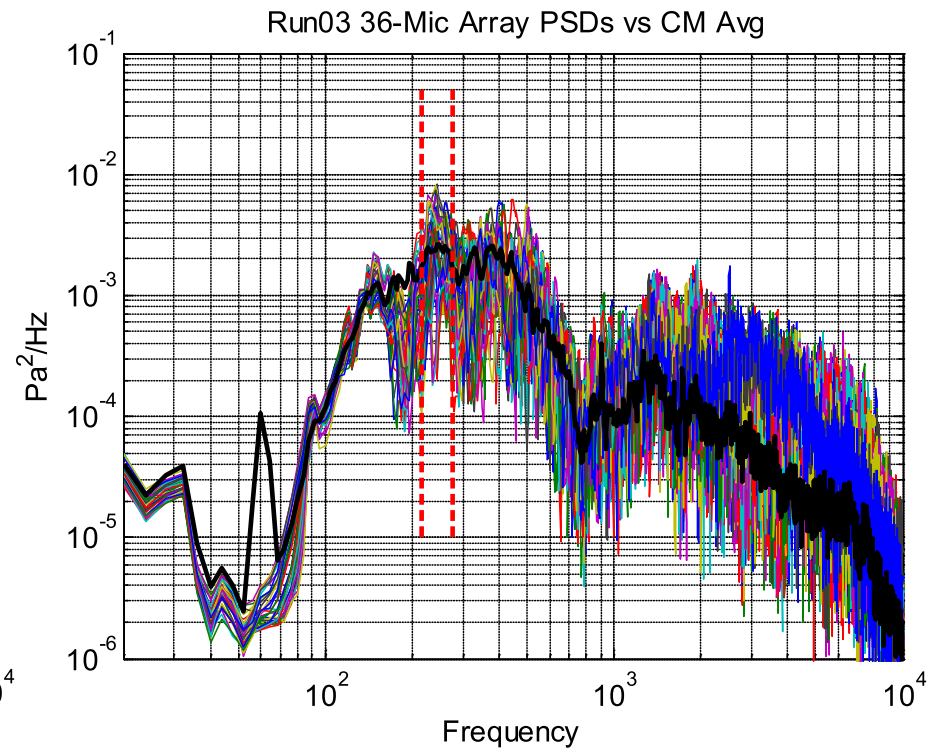
*A. Kolaini, B. Doty, Z. Chang, "Impact of Acoustic Standing Waves on Structural Responses: Reverberant Acoustic Testing (RAT) vs. Direct Field Acoustic Testing (DFAT)", 27th Aerospace Testing Seminar, Oct 2012

Frequency Slices for Single Driver Excitation Studies

Single sub-bass excitation (OASPL = 91 dB)



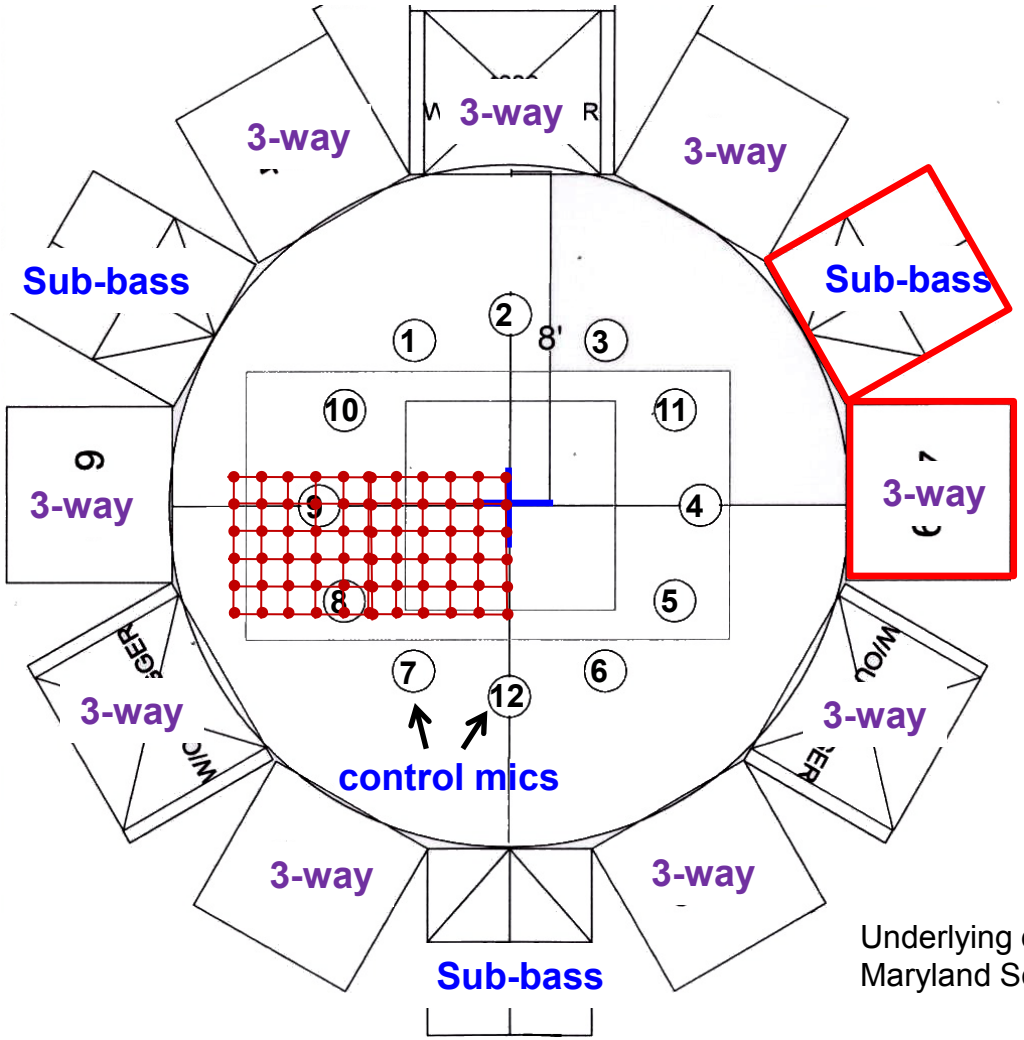
Single 3-way excitation (OASPL = 94 dB)



- Frequency slices chosen
  - *Sub-bass: 80, 88, 100, 216*
  - *3-way: 216, 276*

Configuration for Single Source Excitation; Horizontal Array

Mic array horizontal 92" from floor; two separate runs for contiguous positions



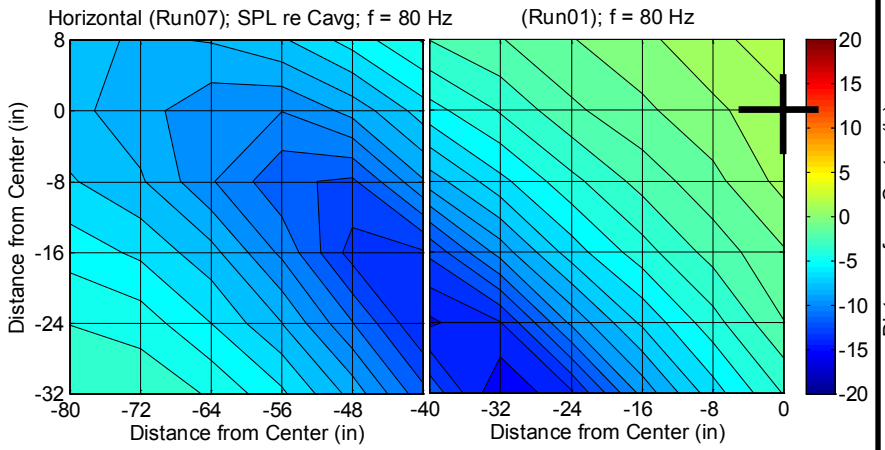
Stack 4

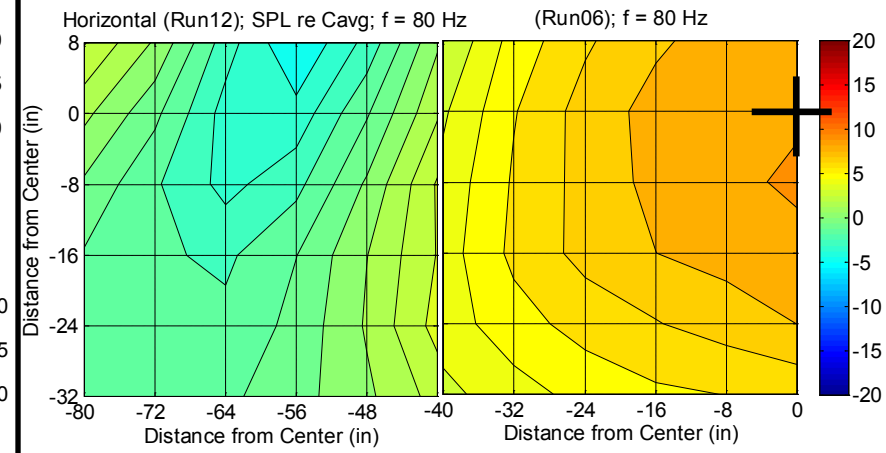
Underlying diagram (B&W) courtesy Maryland Sound International

SPL Variation: Single Source Open Loop vs MIMO Control

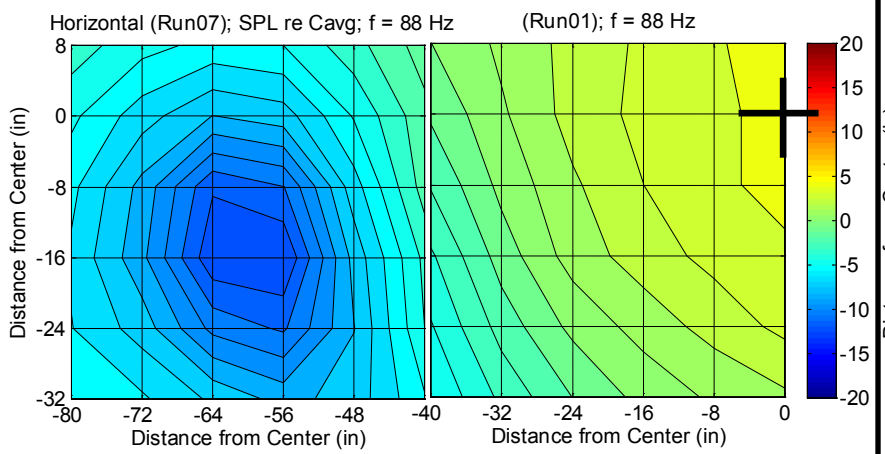
Sub-bass #4, Stack 11 | **All Sources; MIMO Control**

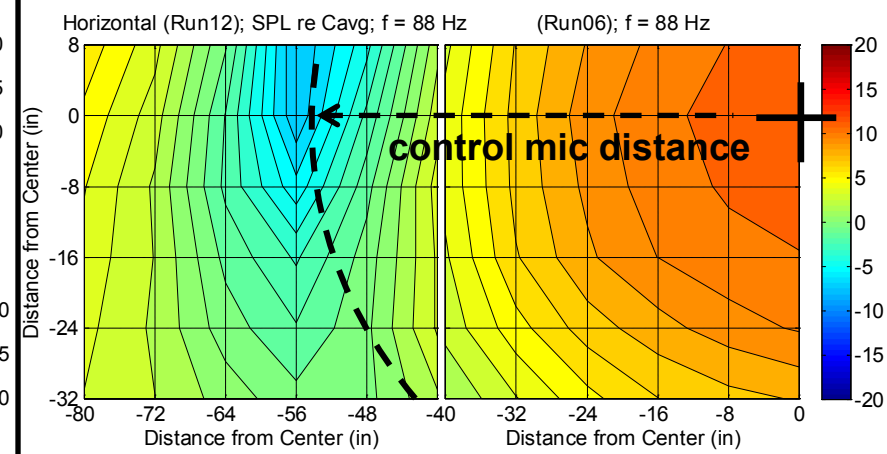
80 Hz





88 Hz



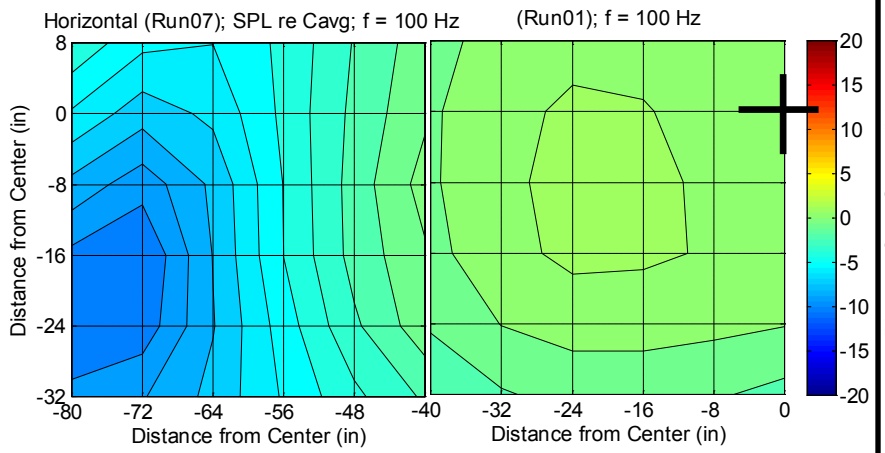


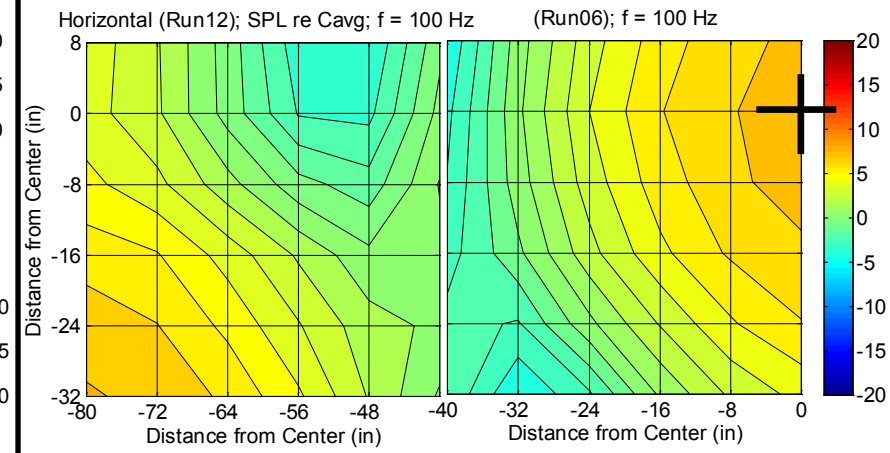
microphone array – horizontal position; 96” from floor

SPL Variation: Single Source Open Loop vs MIMO Control

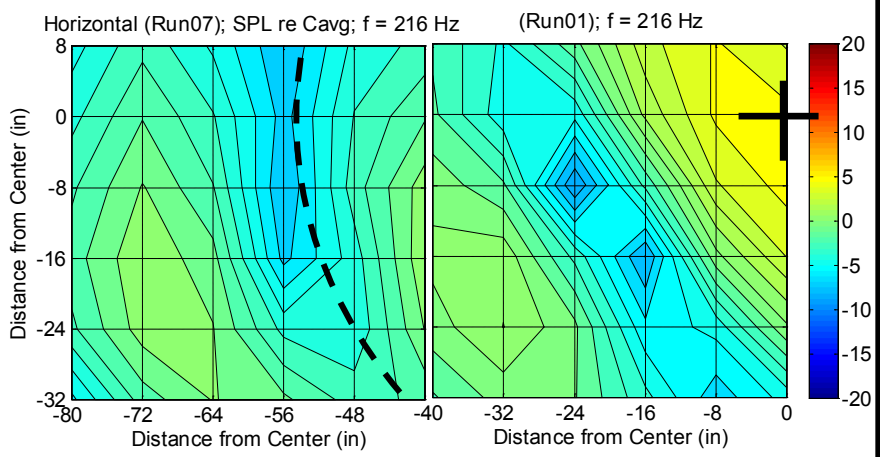
Sub-bass #4, Stack 11 | **All Sources; MIMO Control**

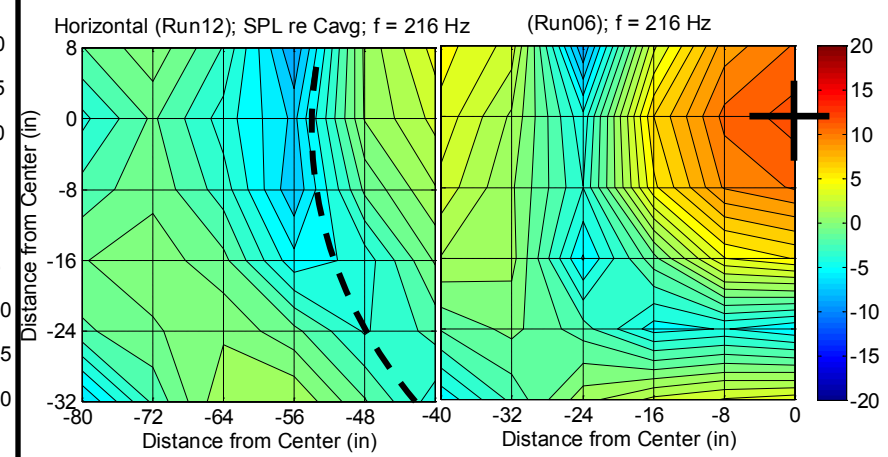
100 Hz





216 Hz





microphone array – horizontal position; 96” from floor

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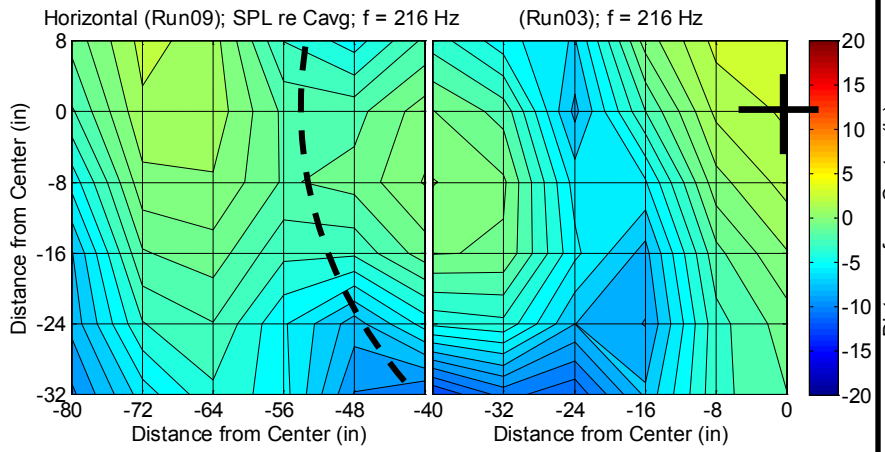
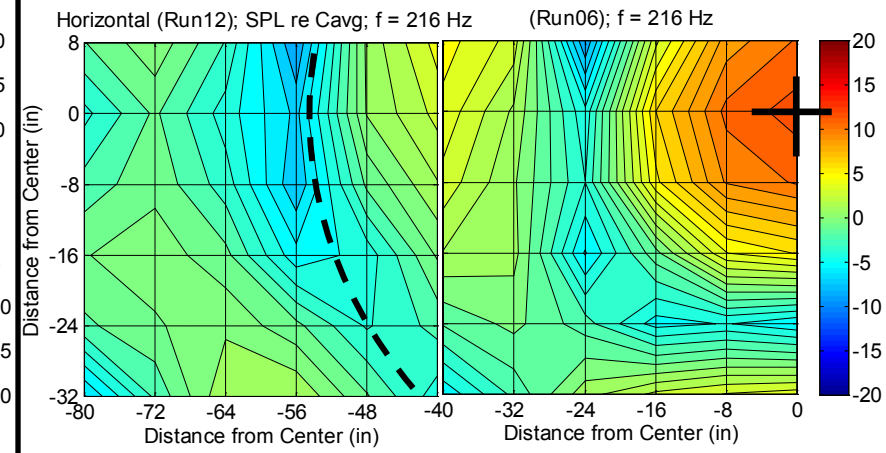
SPL Variation: Single Source Open Loop vs MIMO Control

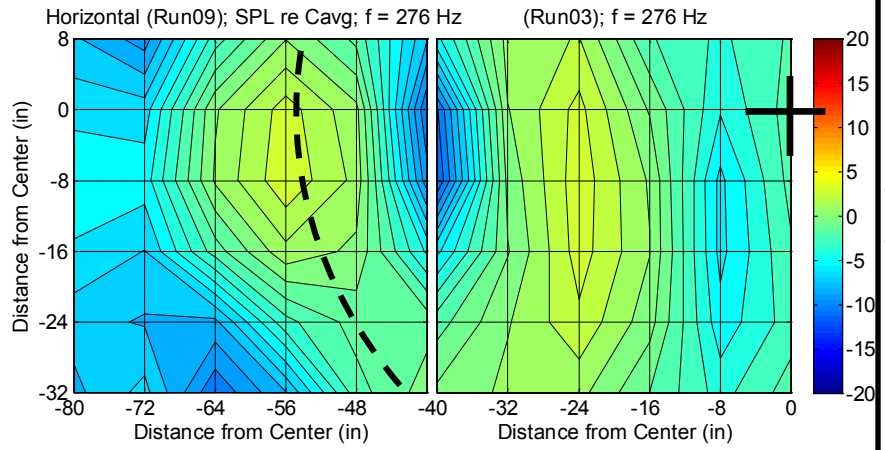
3-way #5, Stack 4 | **All Sources; MIMO Control**

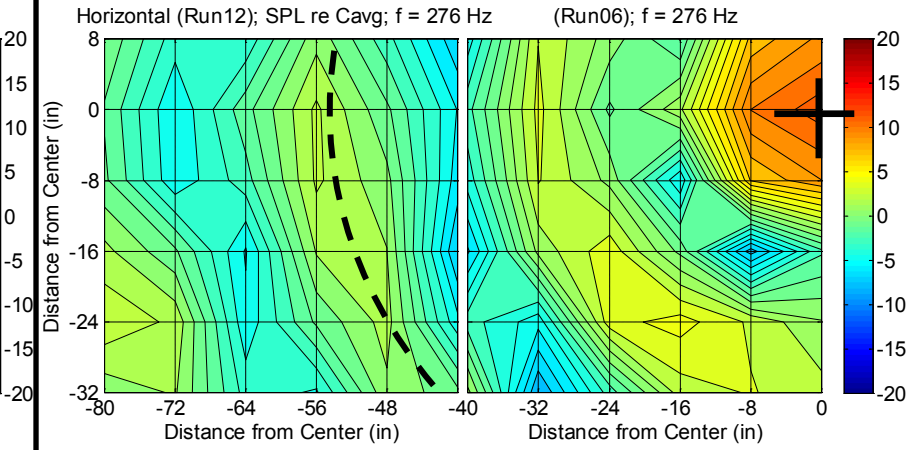
216 Hz





277 Hz

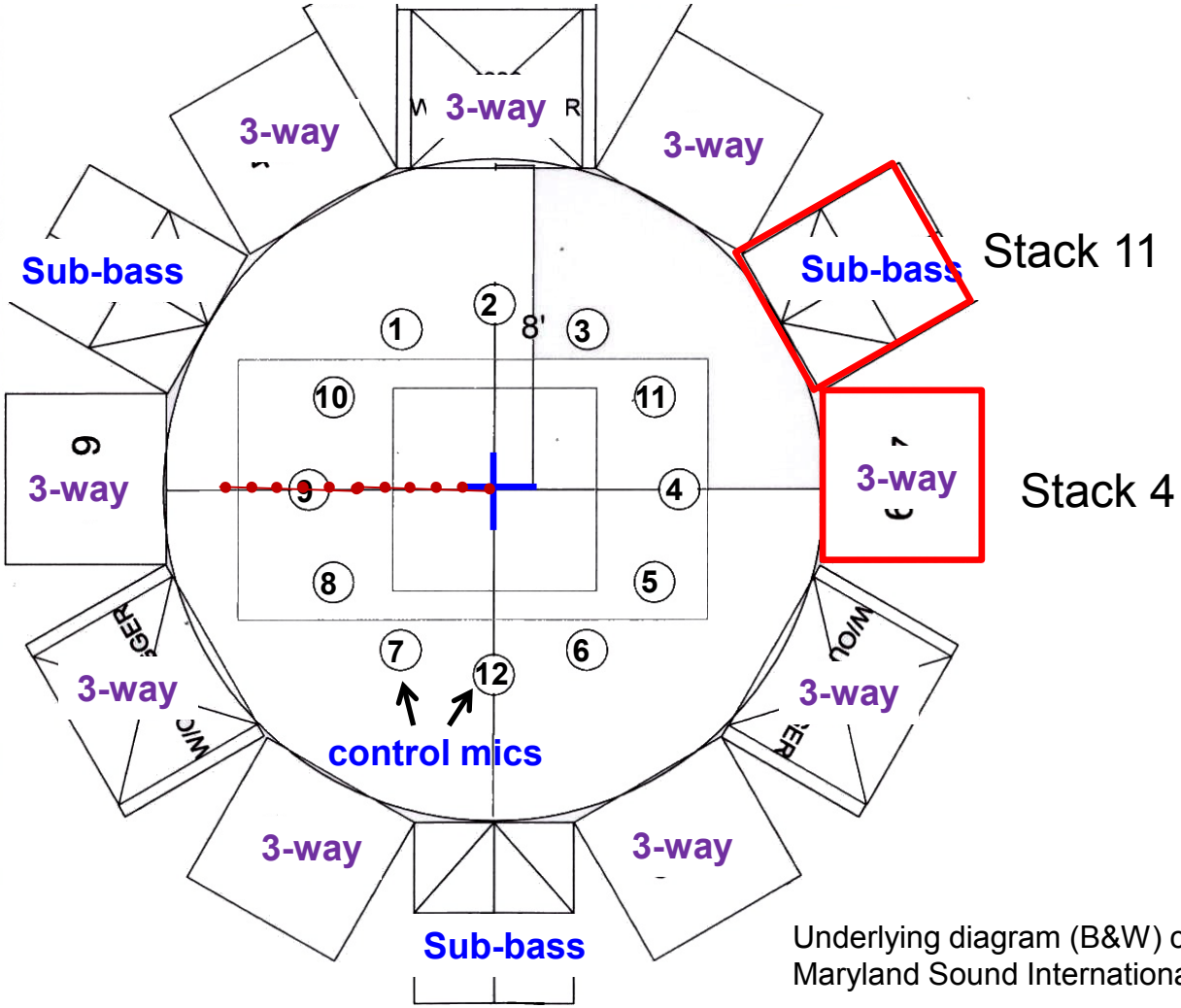




microphone array – horizontal position; 96” from floor

Configuration for Single Source Excitation; Vertical Array

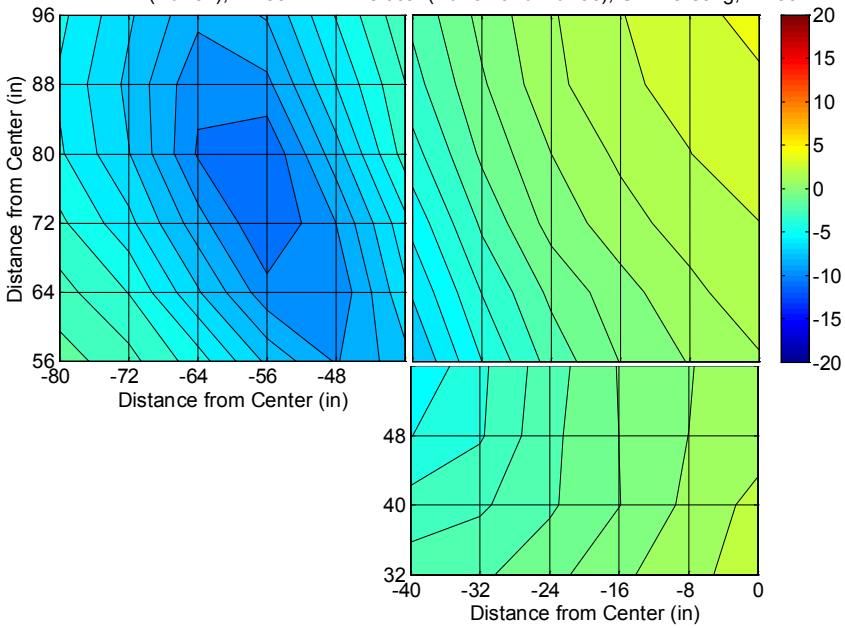
Separate runs for contiguous vertical positions

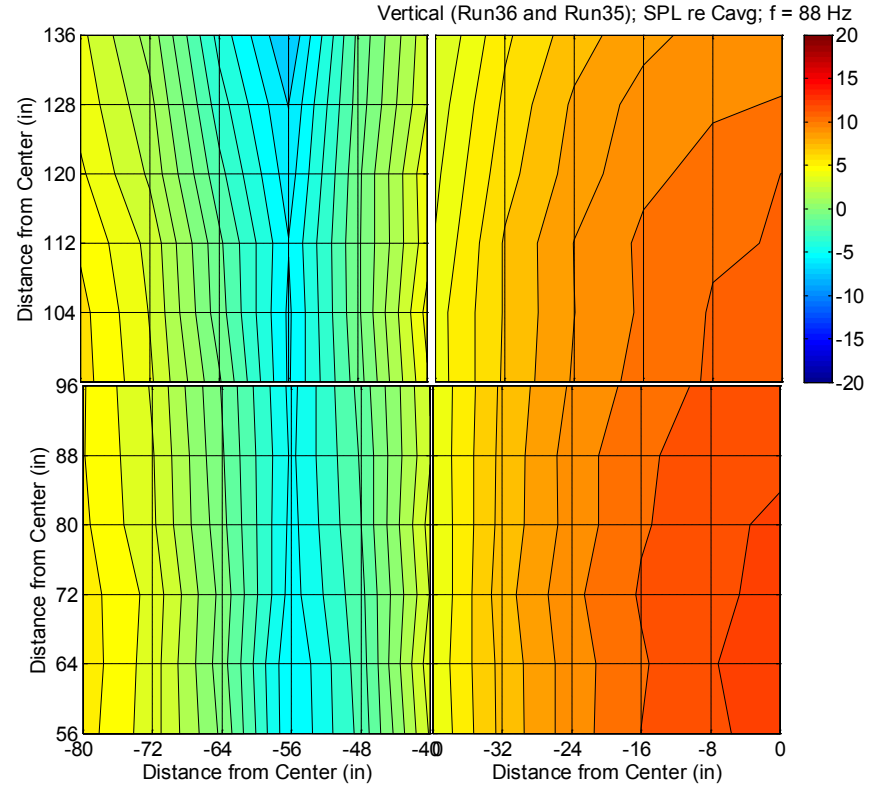


Underlying diagram (B&W) courtesy Maryland Sound International

Vertical Slice; Single Sub Open Loop vs. All Drivers MIMO

Single Sub Open Loop **88 Hz** **All Drivers MIMO Control**

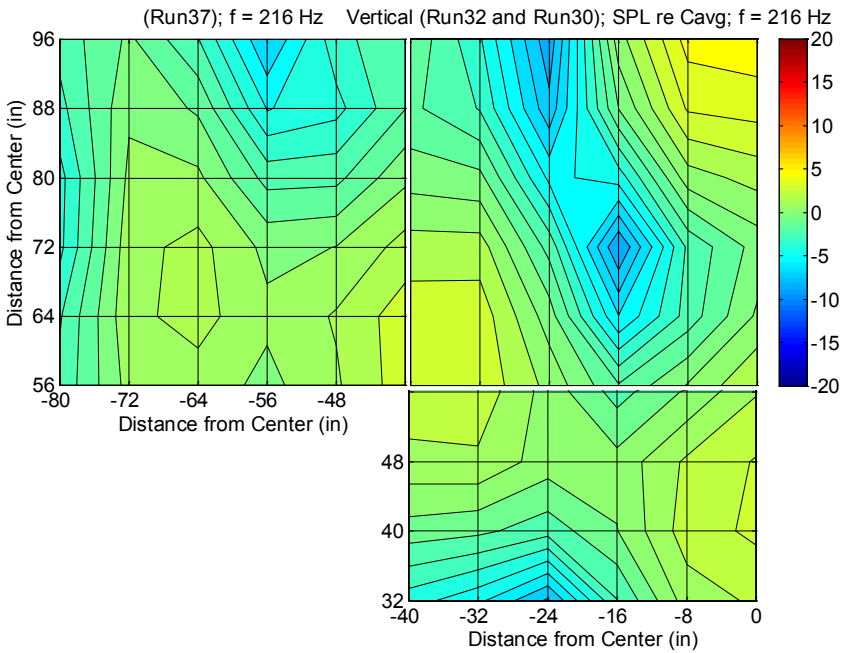


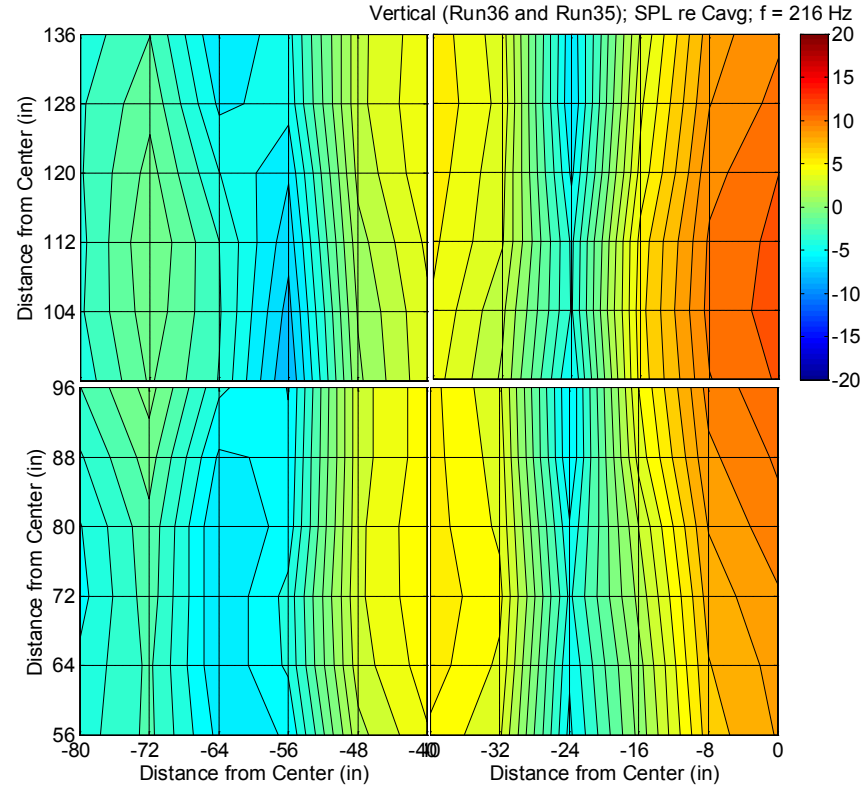


microphone array – vertical positions; from center of test space

Vertical Slice; Single Sub Open Loop vs. All Drivers MIMO

Single Sub Open Loop **216 Hz** **All Drivers MIMO Control**

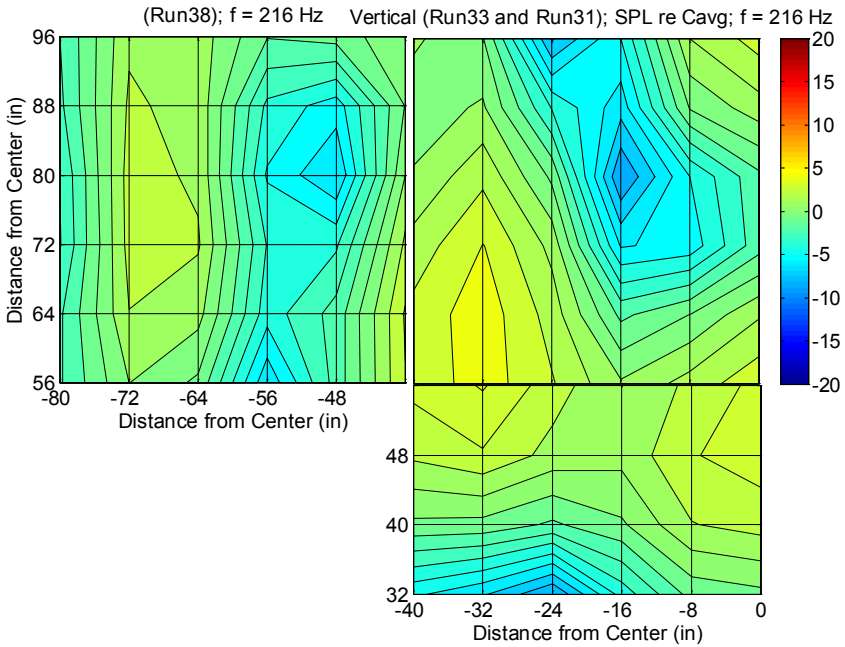


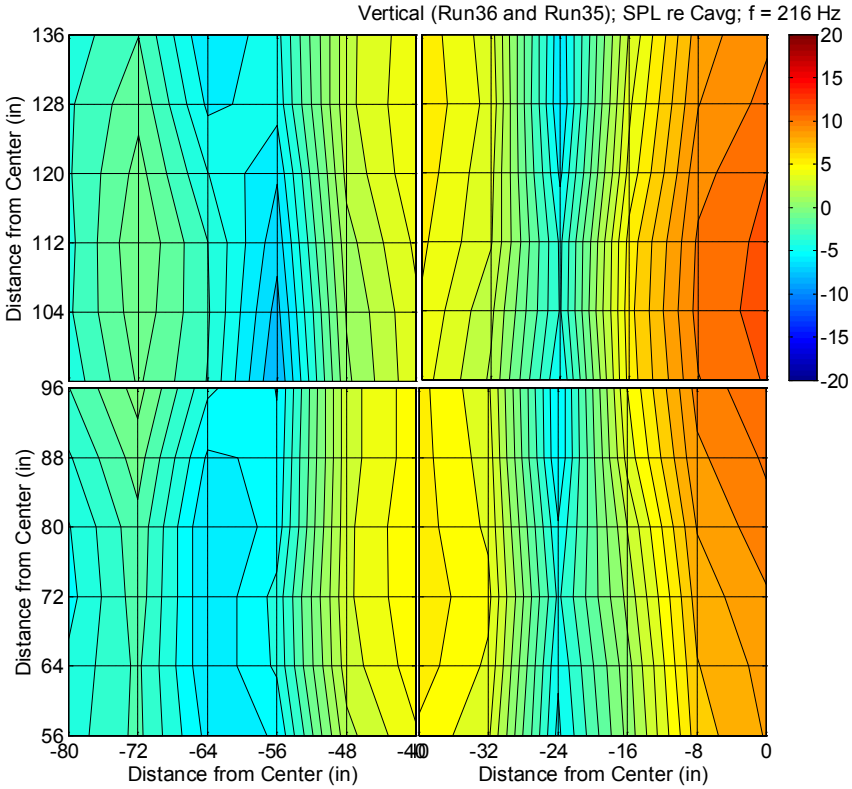


microphone array – vertical positions; from center of test space

Vertical Slice; Single 3-way Open Loop vs. All Drivers MIMO

Single 3-way Open Loop **216 Hz** **All Drivers MIMO Control**

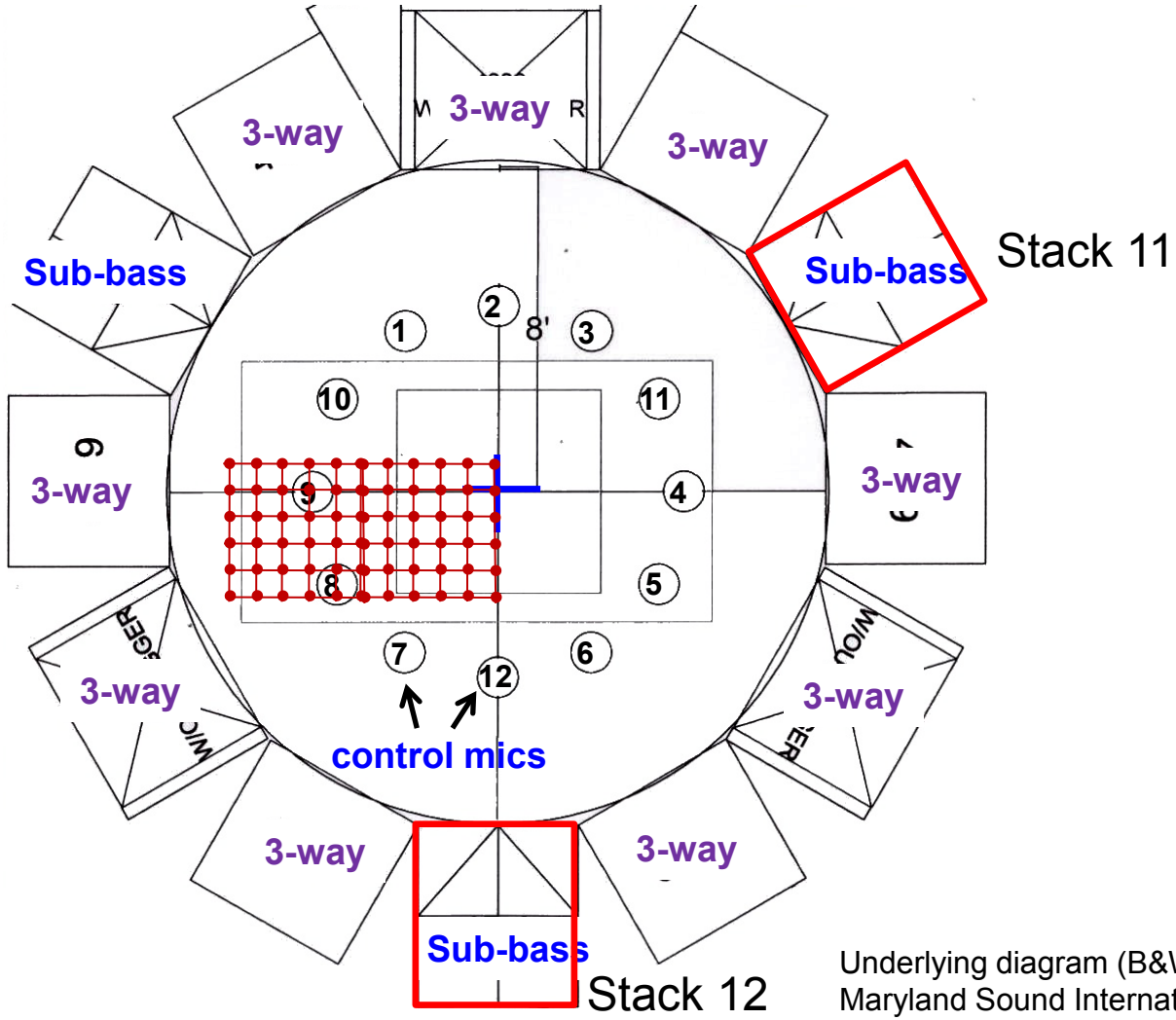




microphone array – vertical positions; from center of test space

Configuration for Single Sub-bass Excitation Comparisons

Mic array horizontal 92" from floor; two separate runs for contiguous positions

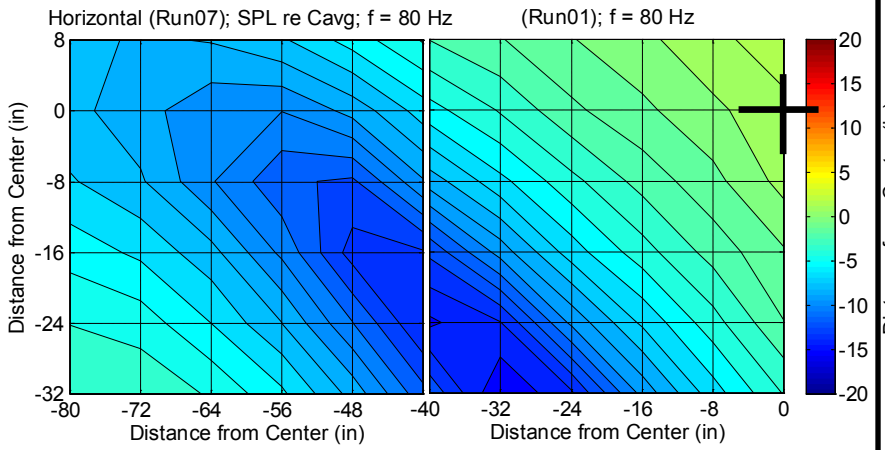


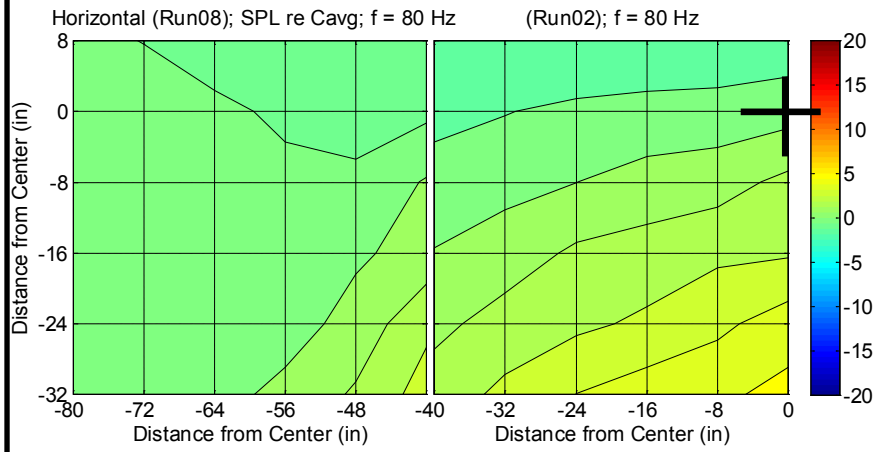
Underlying diagram (B&W) courtesy Maryland Sound International

Different Single Source Locations; Pink Noise Open Loop

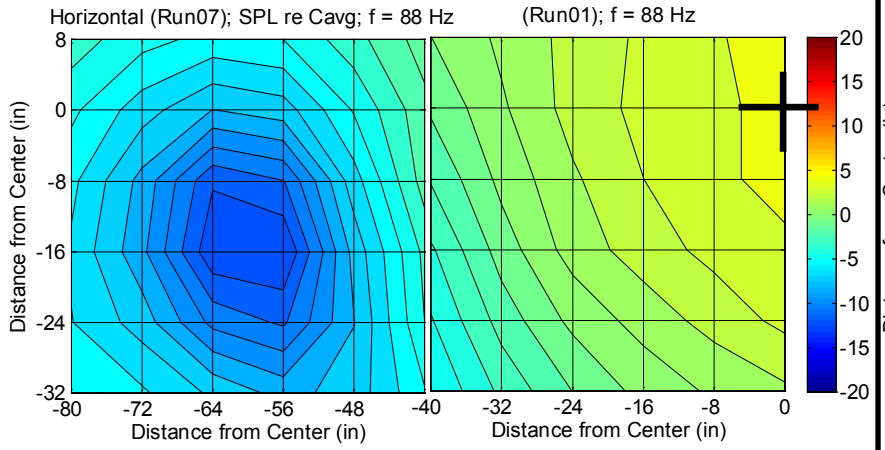
Sub-bass #4, Stack 11 | **Sub-bass #4, Stack 12**

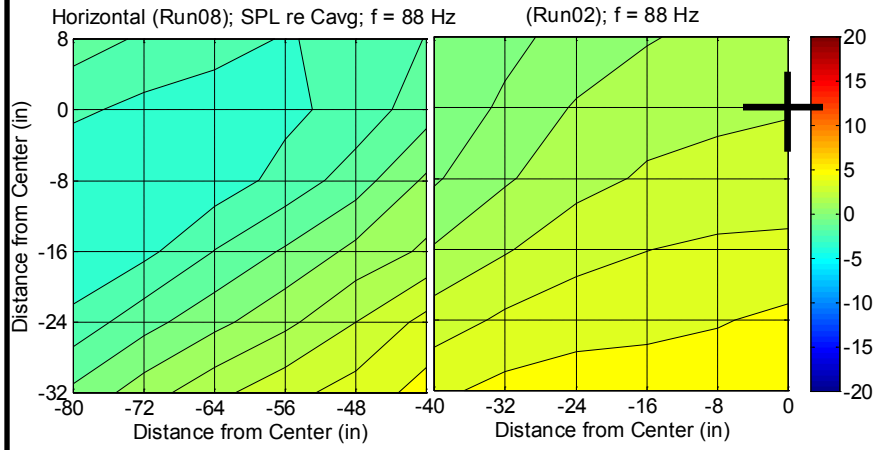
80 Hz





88 Hz



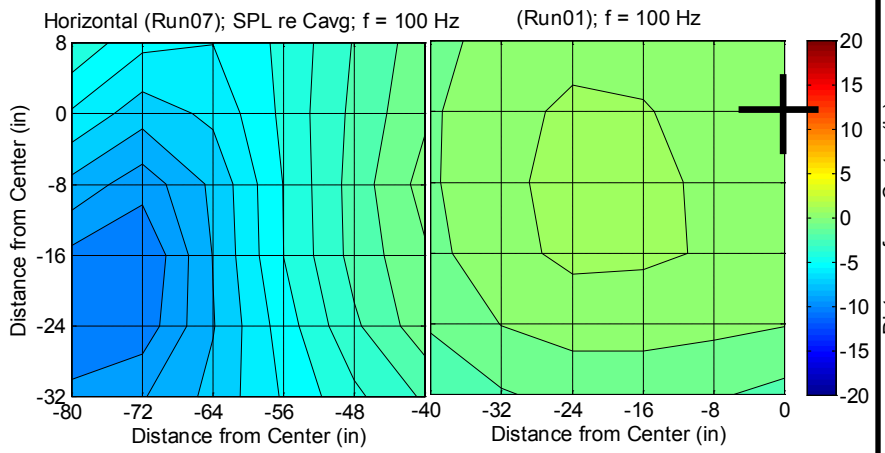


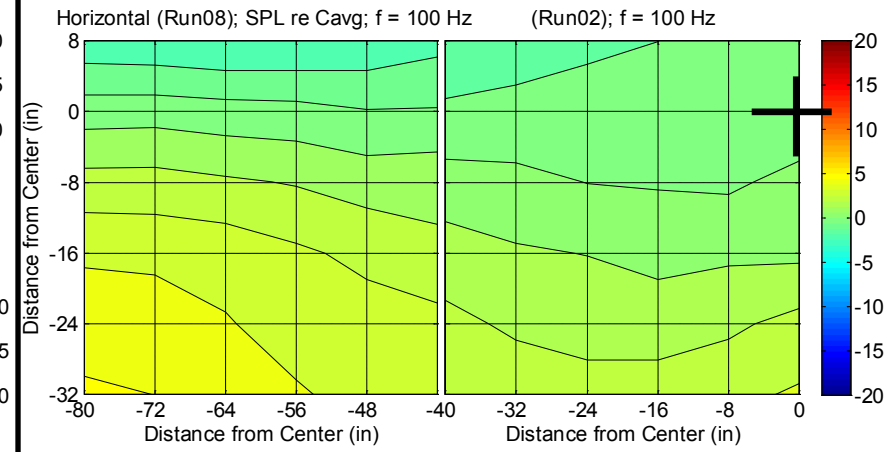
microphone array – horizontal position; 96” from floor

Different Single Source Locations; Pink Noise Open Loop

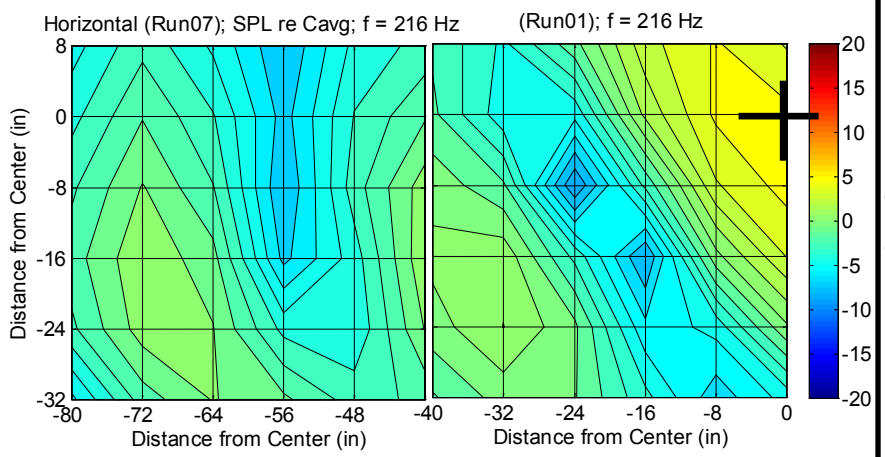
Sub-bass #4, Stack 11 | **Sub-bass #4, Stack 12**

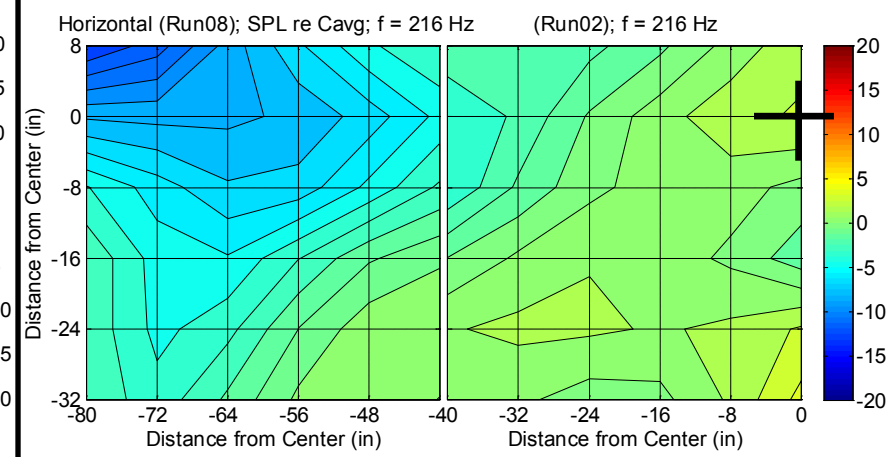
100 Hz





216 Hz

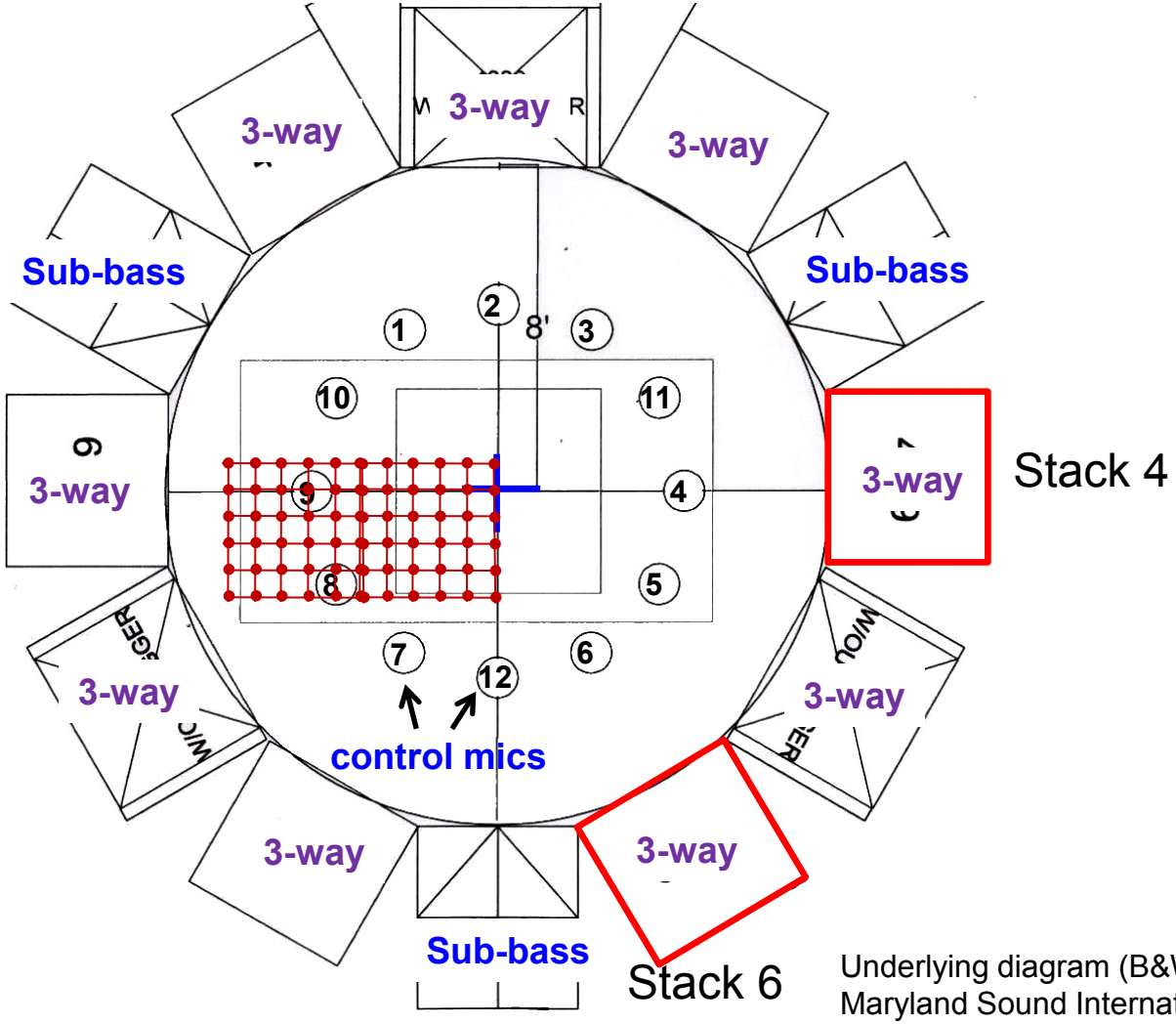




microphone array – horizontal position; 96” from floor

Configuration for Single 3-way Excitation Comparisons

Mic array horizontal 92" from floor; two separate runs for contiguous positions

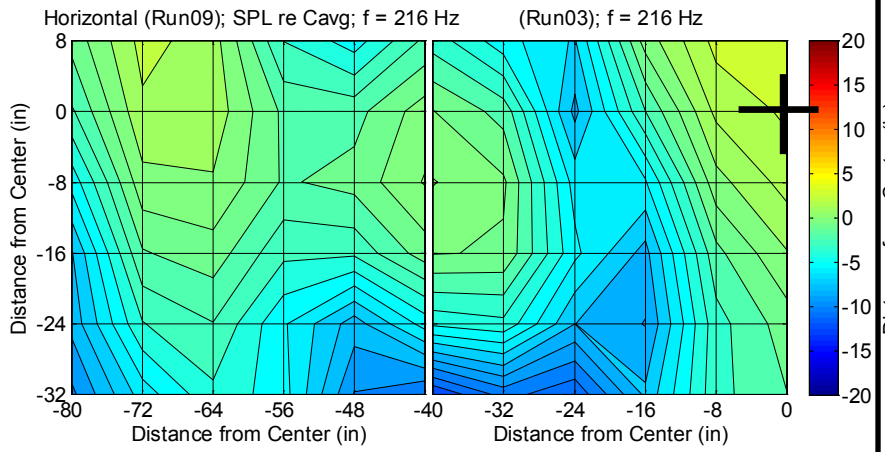


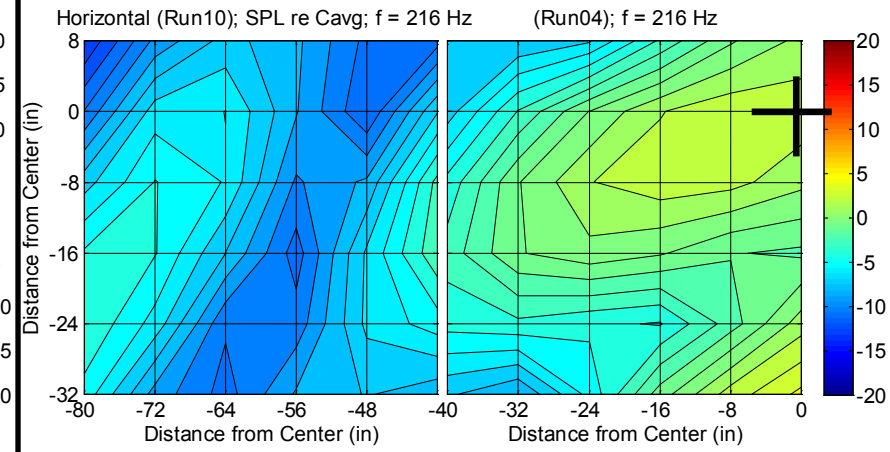
Underlying diagram (B&W) courtesy Maryland Sound International

Different Single Source Locations; Pink Noise Open Loop

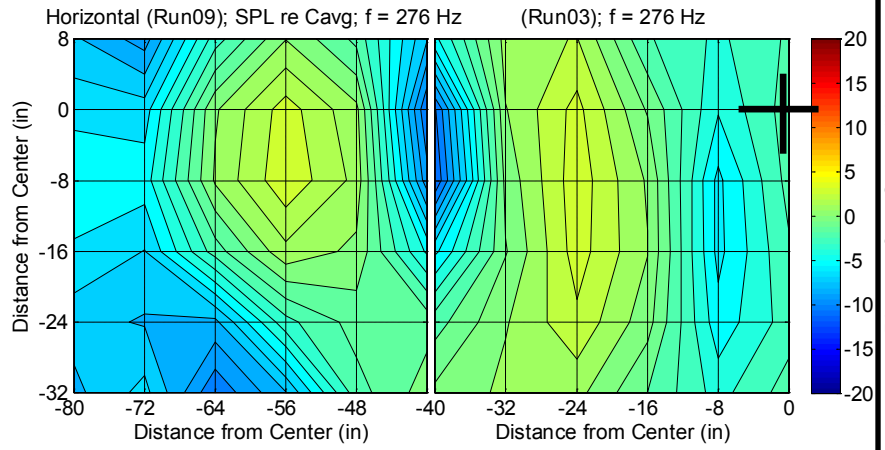
3-way #5, Stack 4 | **3-way #5, Stack 6**

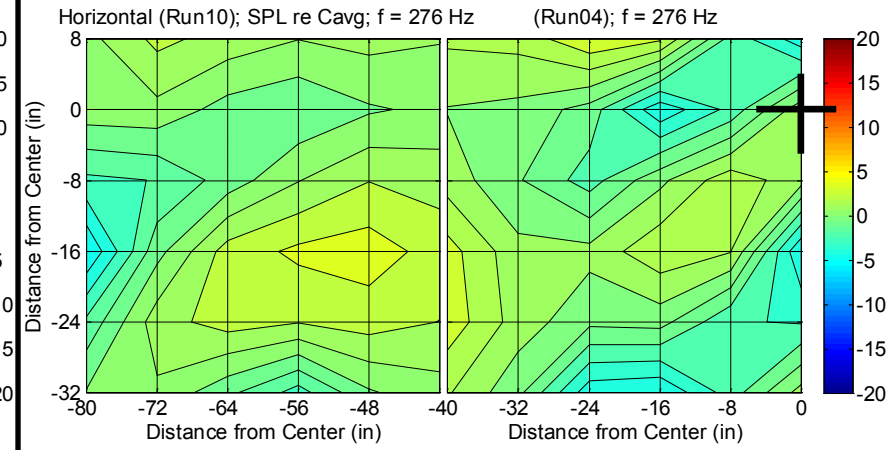
216 Hz





276 Hz





microphone array – horizontal position; 96” from floor

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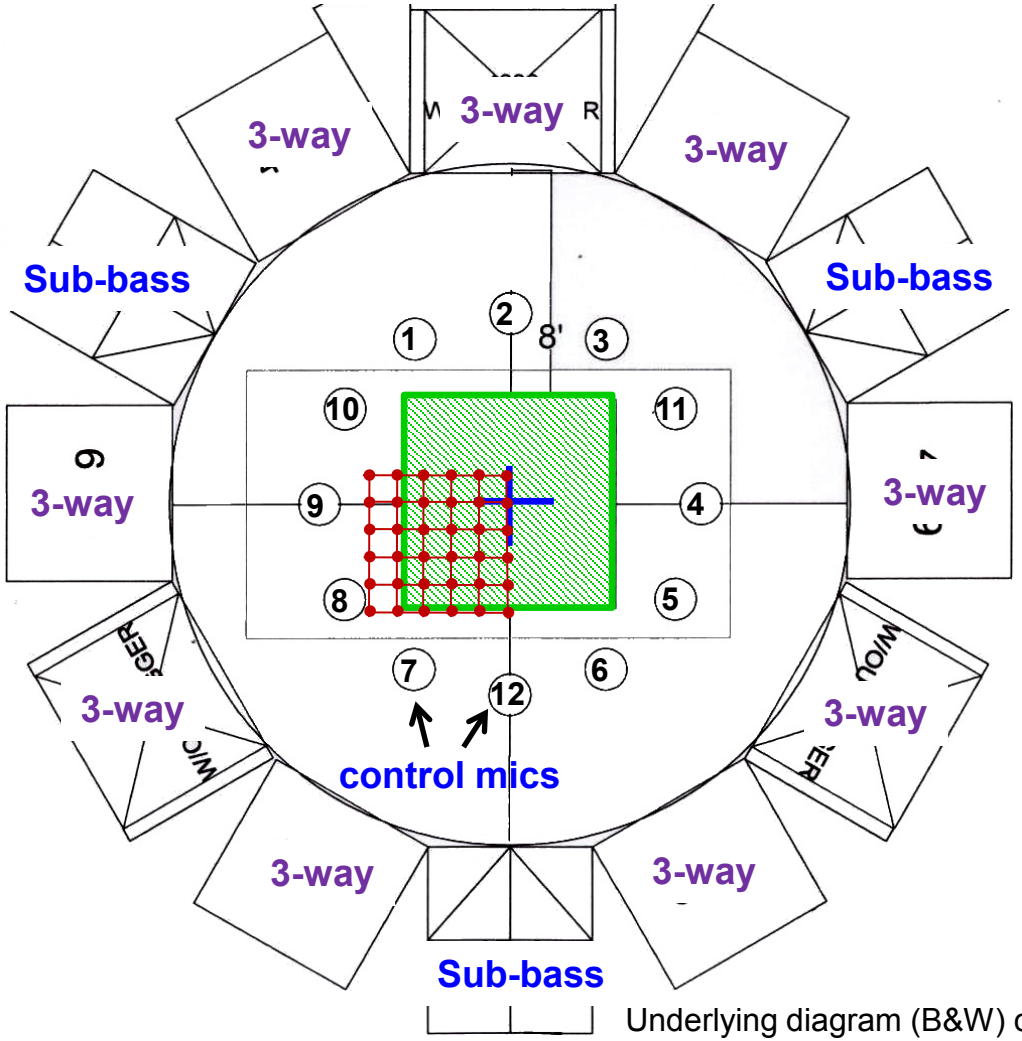
Influence of Presence of SC Simulator

All sources; MIMO Control at 140.3 dB overall

- Comparison of measurements with and without SC Simulator
- Locations used for 36-microphone array common to both configurations

36-Microphone Array Above SC Simulator

12” above simulator; 162” from floor

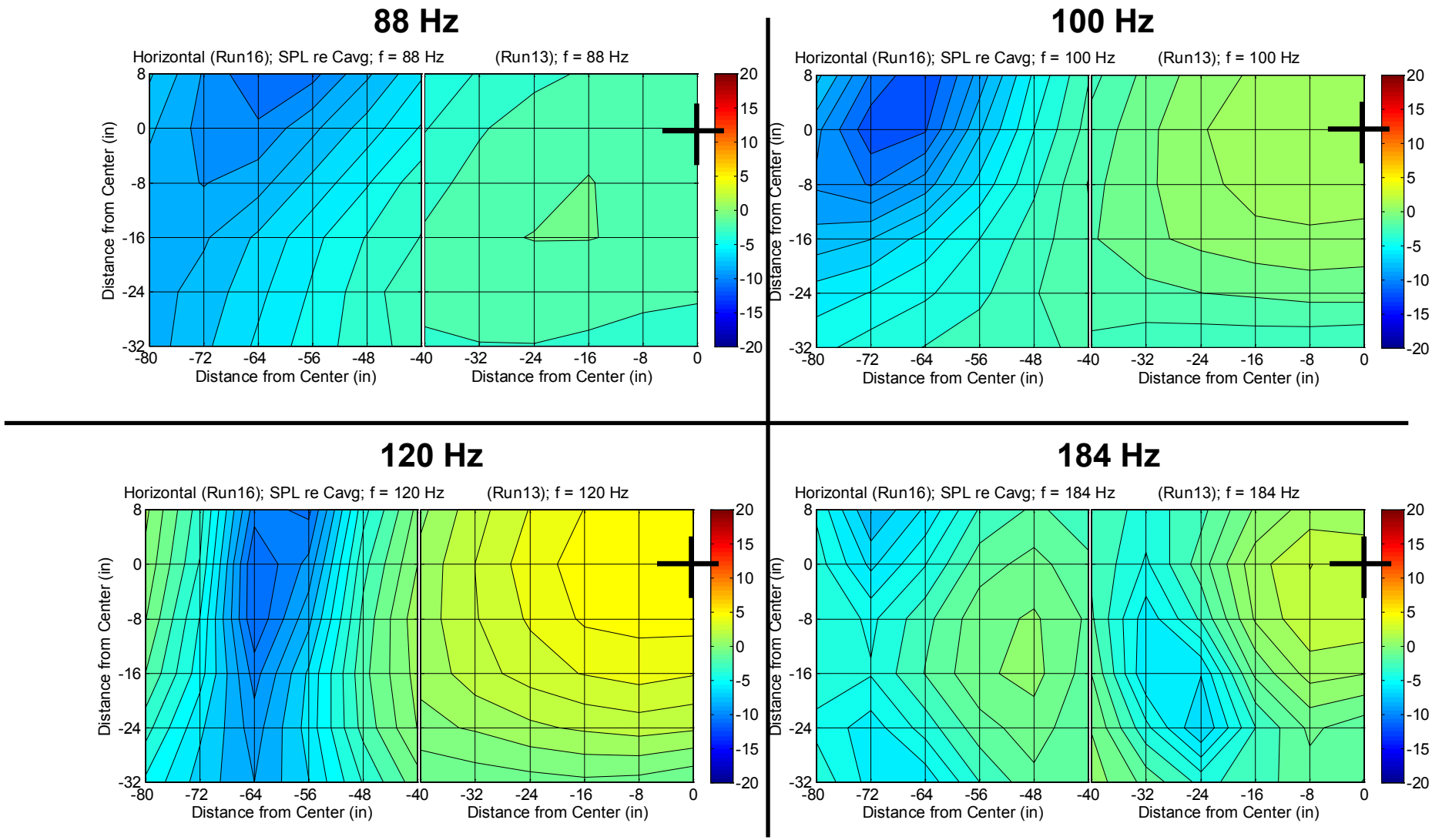


Underlying diagram (B&W) courtesy Maryland Sound International

Courtesy Johns Hopkins Applied Physics Laboratory

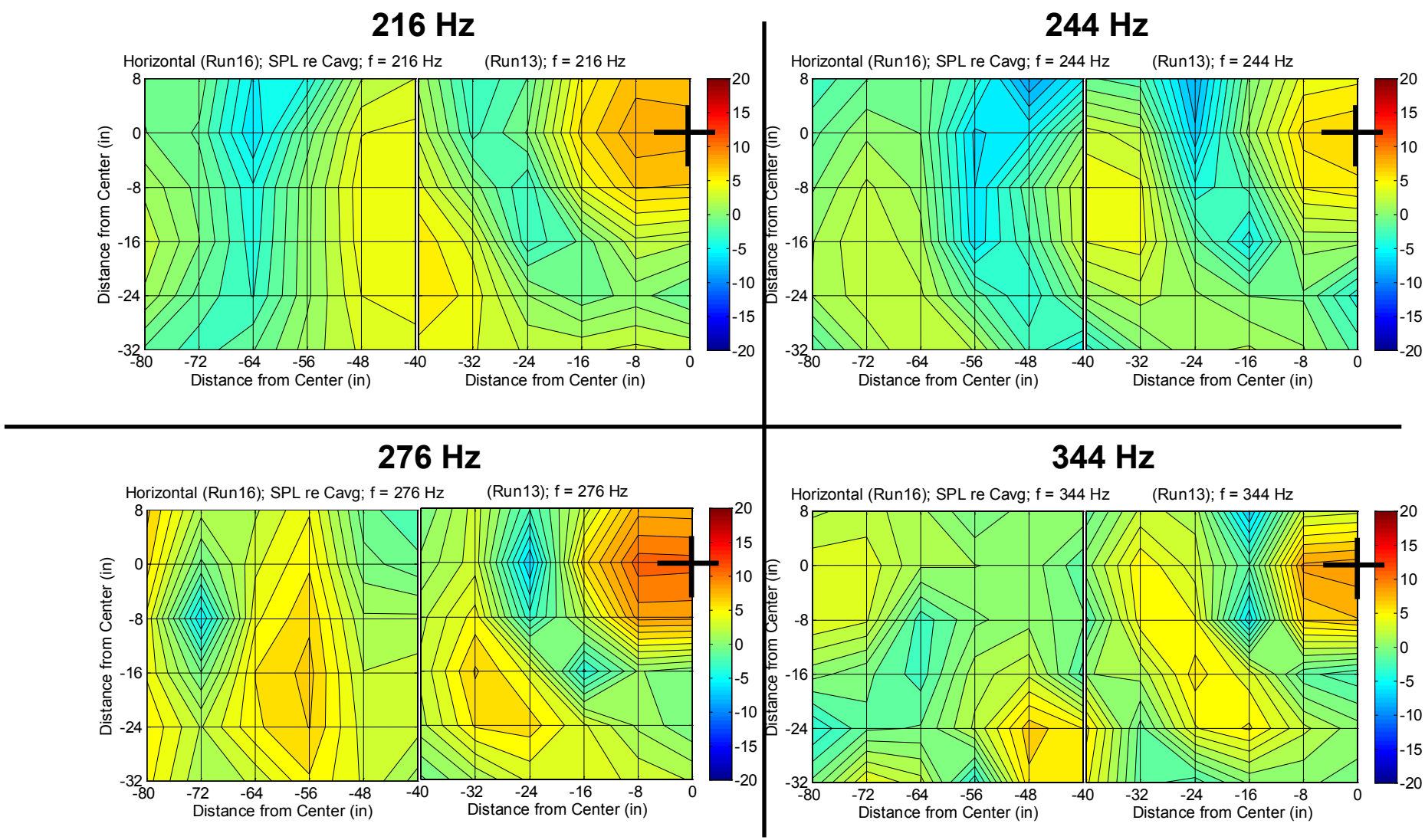
NOTE: Mic array is higher than sub-bass stacks

Mic Array Horizontal Above SC Simulator; MIMO Control



microphone array – horizontal position; 12” above Simulator; 162” from floor

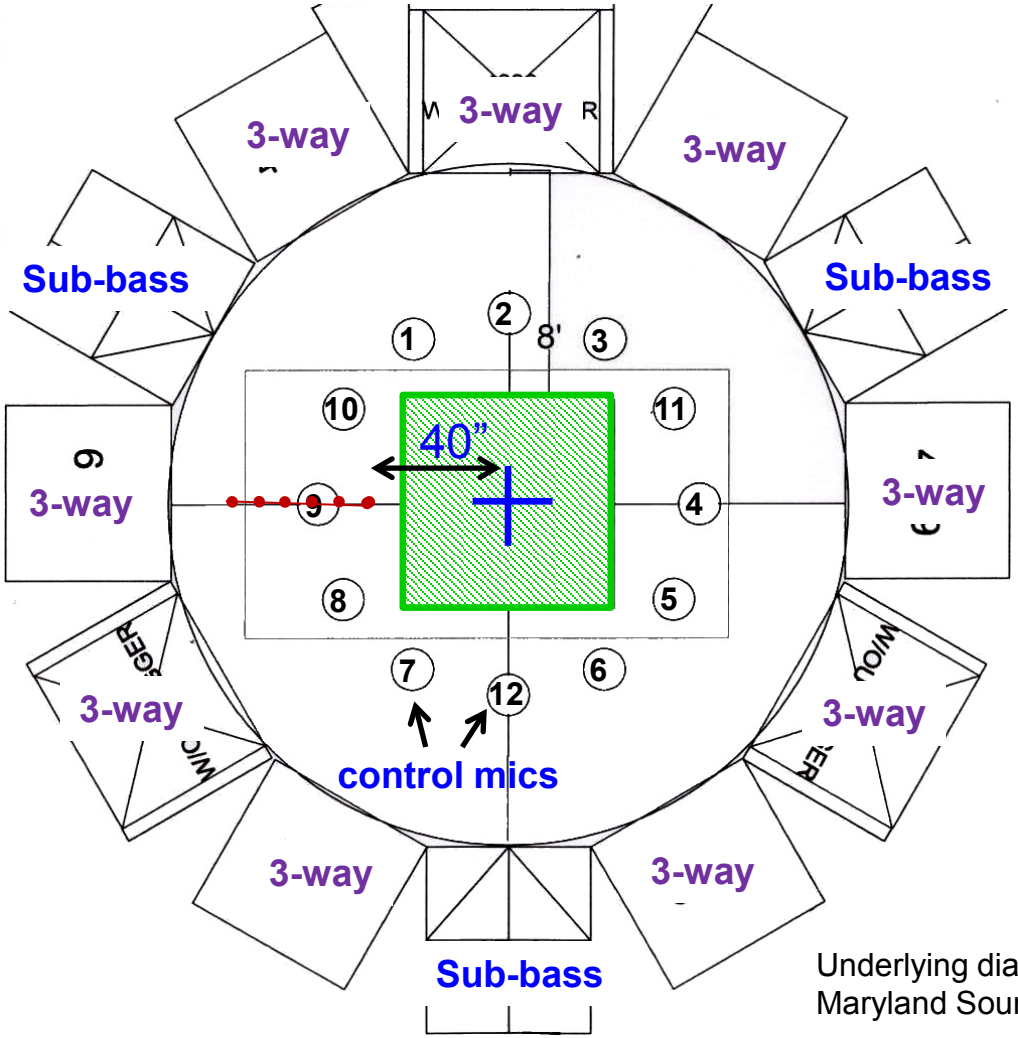
Mic Array Horizontal Above SC Simulator; MIMO Control



microphone array – horizontal position; 12” above Simulator; 162” from floor

36-Microphone Array Configuration with SC Simulator

Separate runs for contiguous vertical positions

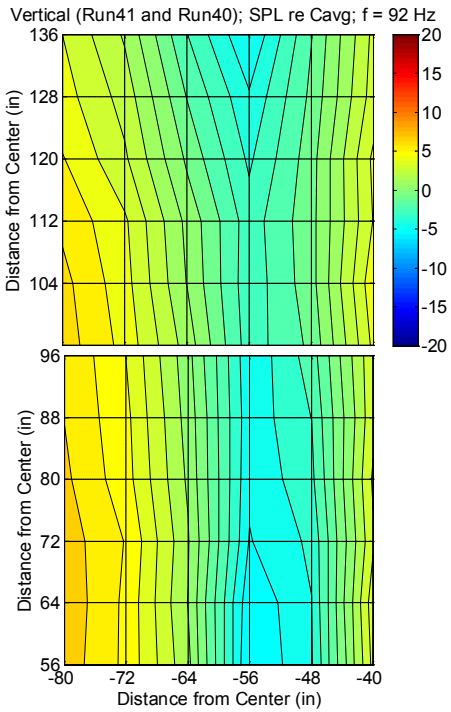


Underlying diagram (B&W) courtesy Maryland Sound International

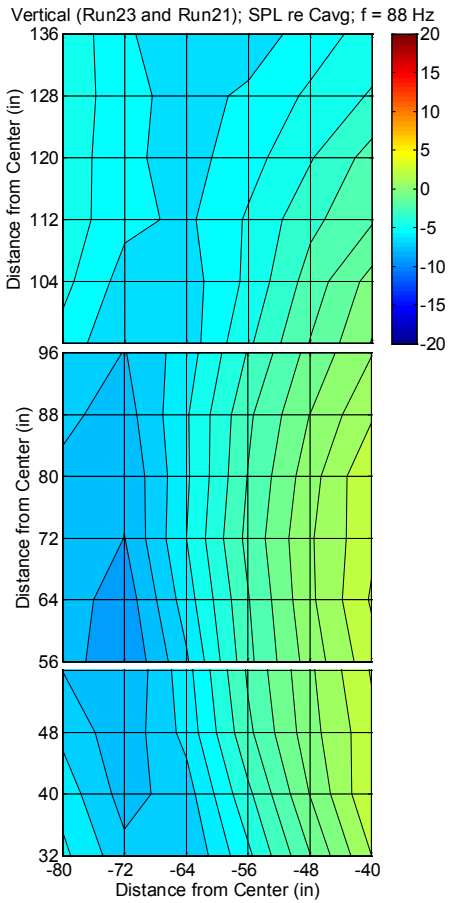
Vertical Without vs. With SC Simulator; MIMO Control

88 Hz

Empty Test Space

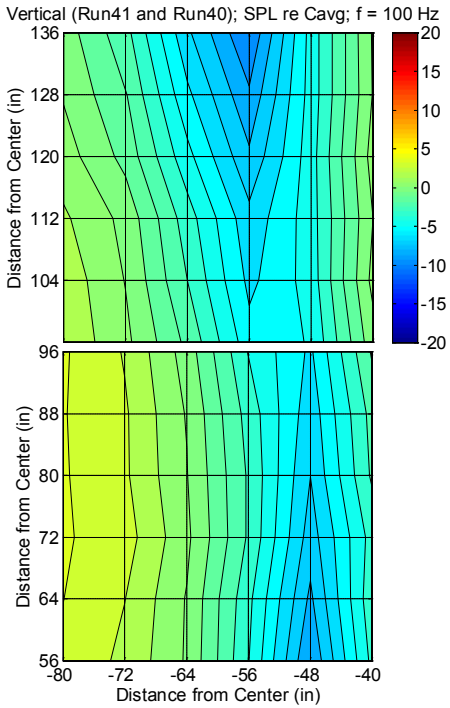


With SC Simulator

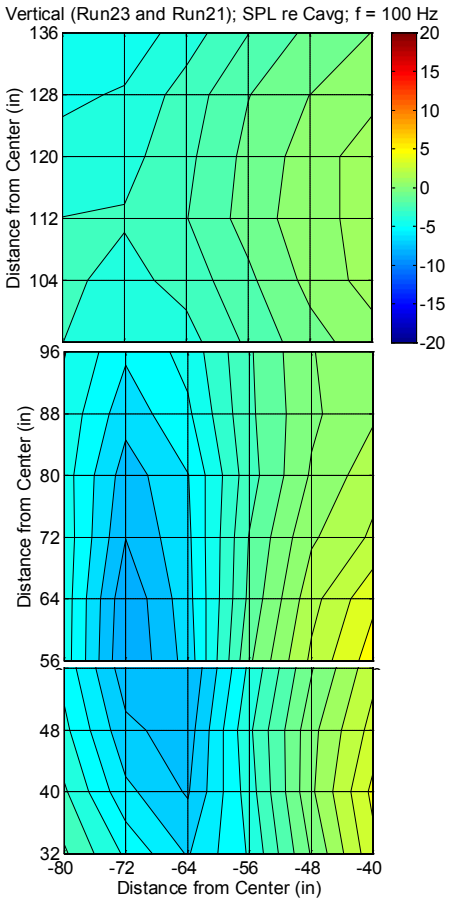


100 Hz

Empty Test Space



With SC Simulator



microphone array – vertical positions; 40” from center of test space

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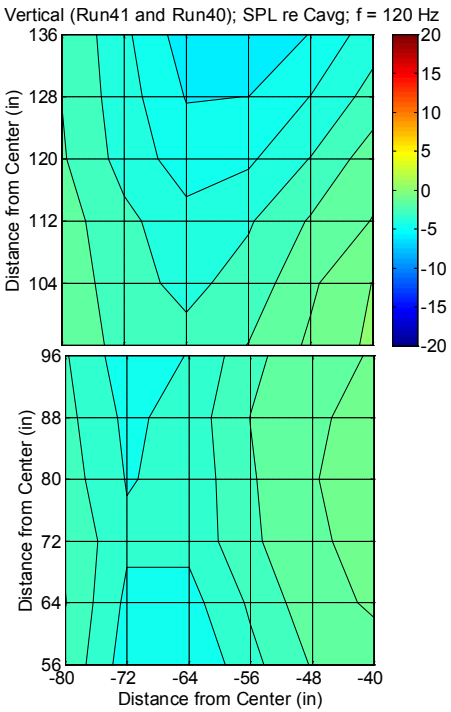
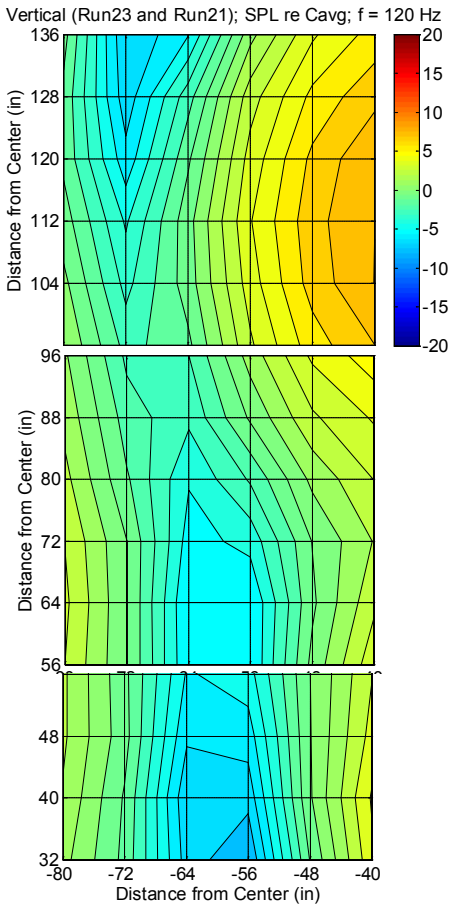
Vertical Without vs. With SC Simulator; MIMO Control

120 Hz

Empty Test Space

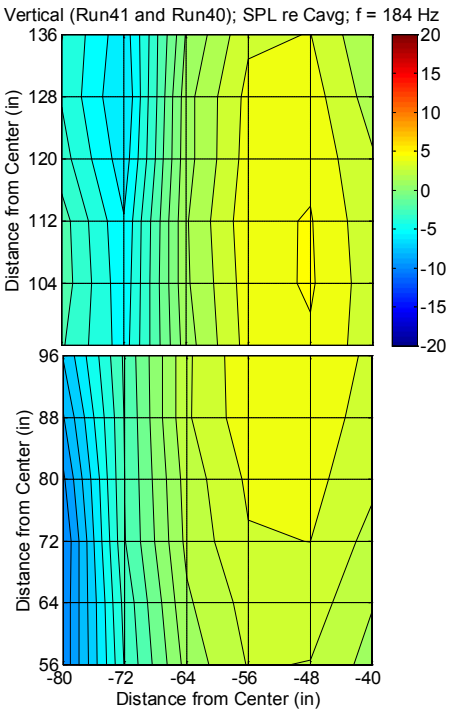


With SC Simulator

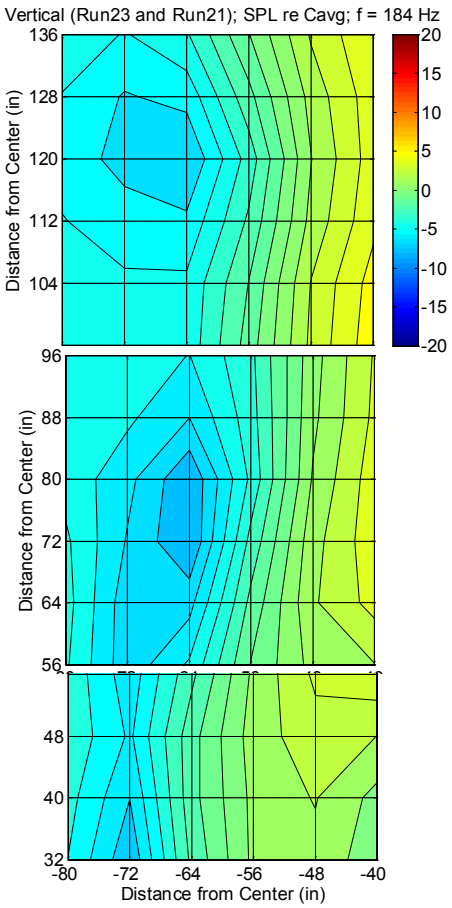


184 Hz

Empty Test Space



With SC Simulator



microphone array – vertical positions; 40” from center of test space

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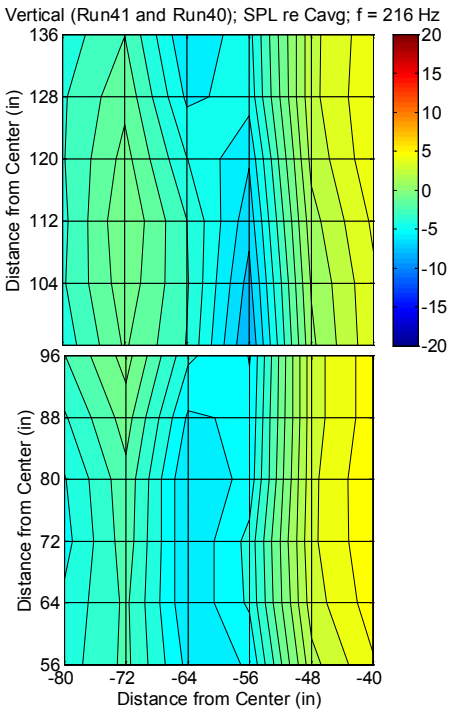
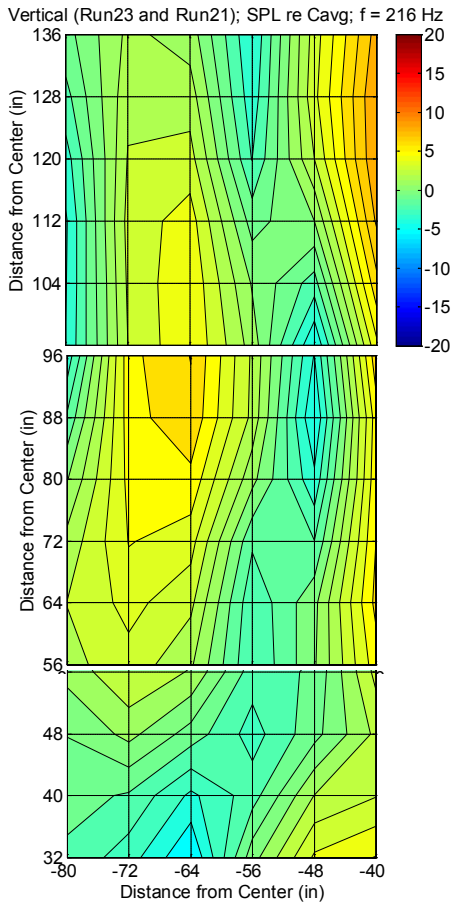
Vertical Without vs. With SC Simulator; MIMO Control

216 Hz

Empty Test Space

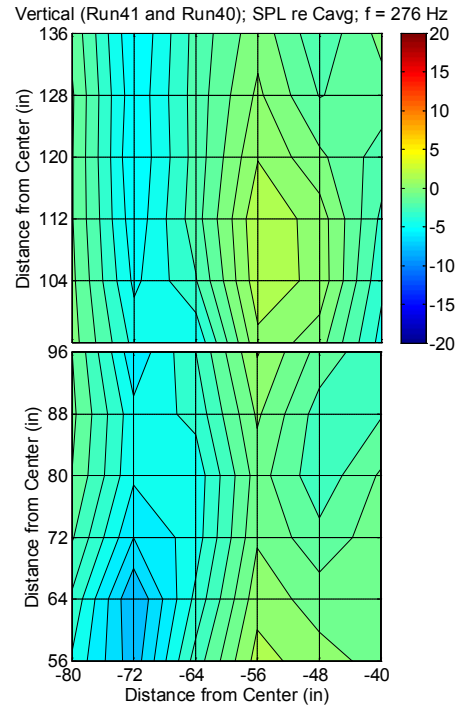


With SC Simulator

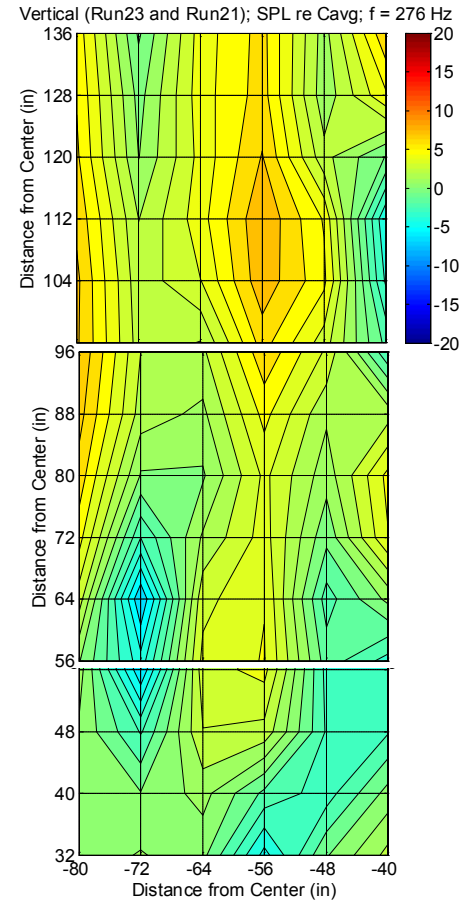


276 Hz

Empty Test Space



With SC Simulator



microphone array – vertical positions; 40” from center of test space

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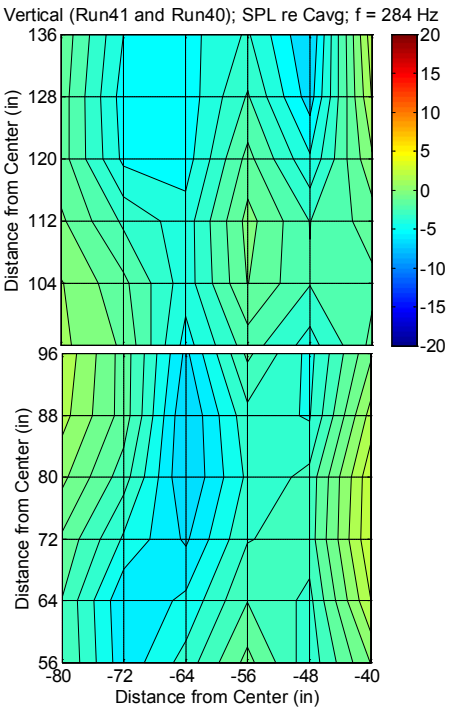
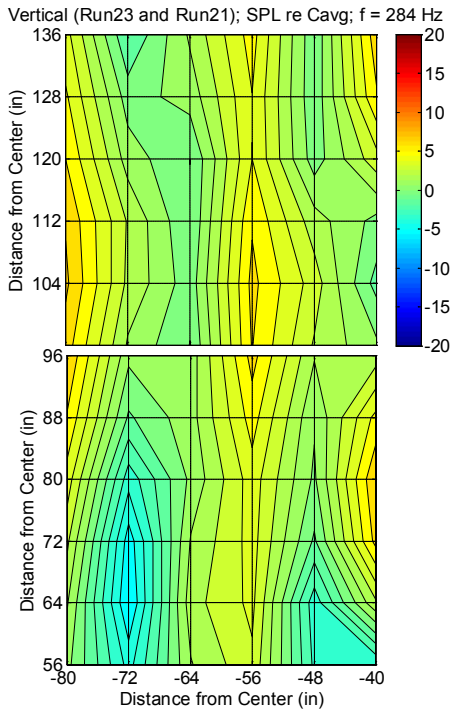
Vertical Without vs. With SC Simulator; MIMO Control

284 Hz

Empty Test Space

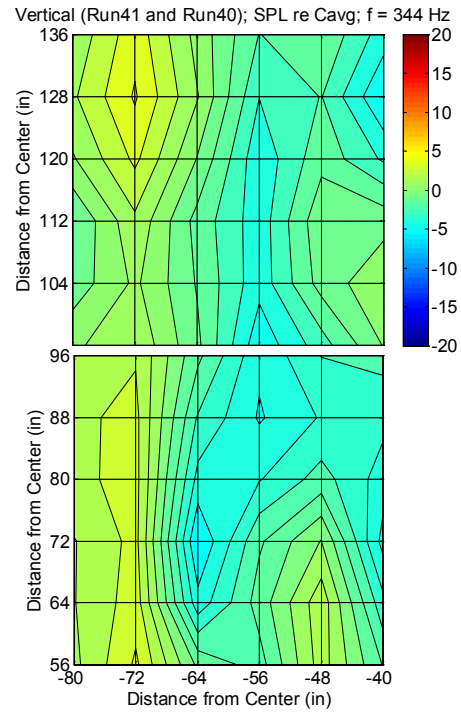


With SC Simulator

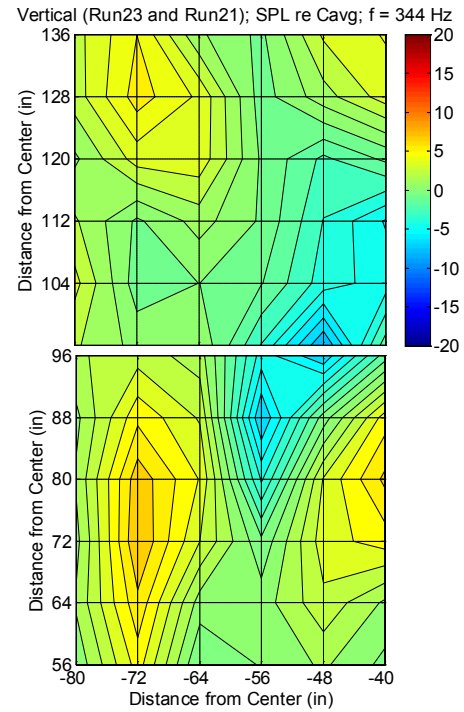


344 Hz

Empty Test Space



With SC Simulator



microphone array – vertical positions; 40” from center of test space

Observations

- Single source excitation showed evidence of standing waves, but not clearly associated with speaker array
  - *Observed patterns may largely be associated with high bay modes and/or interference from floor reflections*
- Observations do not necessarily discount presence of standing waves at 88 Hz and 216 Hz during full level MIMO testing
  - *Single low level source (90 – 94 dB) may not provide sufficient energy for such a large volume to generate modal response*
- Difficulty with control at 88 Hz and 216 Hz may be related to fact that control microphones lie along an acoustic minimum
- Influence of SC simulator on MIMO test field
  - *Between simulator and speakers – changes and may intensify acoustic spatial patterns*
  - *Above simulator – characterized by apparent wave interference patterns*
    - MIMO control does not appear to mitigate – likely due to no control mics present in this area

Future Work

- Analyze time history microphone array data
  - *Spatial coherence*
  - *Power flow*
- Analyze SC simulator accelerometer responses and compare to single-input-single-output and acoustic chamber tests
- Data available for development and correlation of BEM models

Thank you

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