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System Optimization and Measurement

The Search for Actionable Data

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Presenter: Jamie Anderson

2008 – Present: Rational Acoustics LLC

Founding Partner, Head Instructor & Systweak

1999 – 2008: SIA Software / EAW / LOUD Technologies

SIA-Smaart Product Manager, EAW Brand Product Manager

1997 – 1999: Independent Sound Engineer

A-1 Audio, Meyer Sound, Solstice, UltraSound / Promedia

1992 – 1997: Meyer Sound Laboratories

SIM & Technical Support Manager

Education

MFA: Yale School of Drama

BS EE/Physics: Worcester Polytechnic University

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System Alignment
&
System Engineering

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Who Are You?

System Designer?
Architect / Room Designer?
System Engineer?
Mix Engineer?
Acoustical Consultant?
Musician?

Churches?
Live Music?
Schools?
Bars / Clubs?

Design vs. Du Jour?

Assemble / Install Systems?
Build Rooms / Sound Studios?
Tune Sound Systems?
Live Sound Mixer?
Studio Mixer?
Systems Maintenance?

Touring/Temporary Sound?
Permanent Installation?

Life Safety Systems?

Do you know your job?

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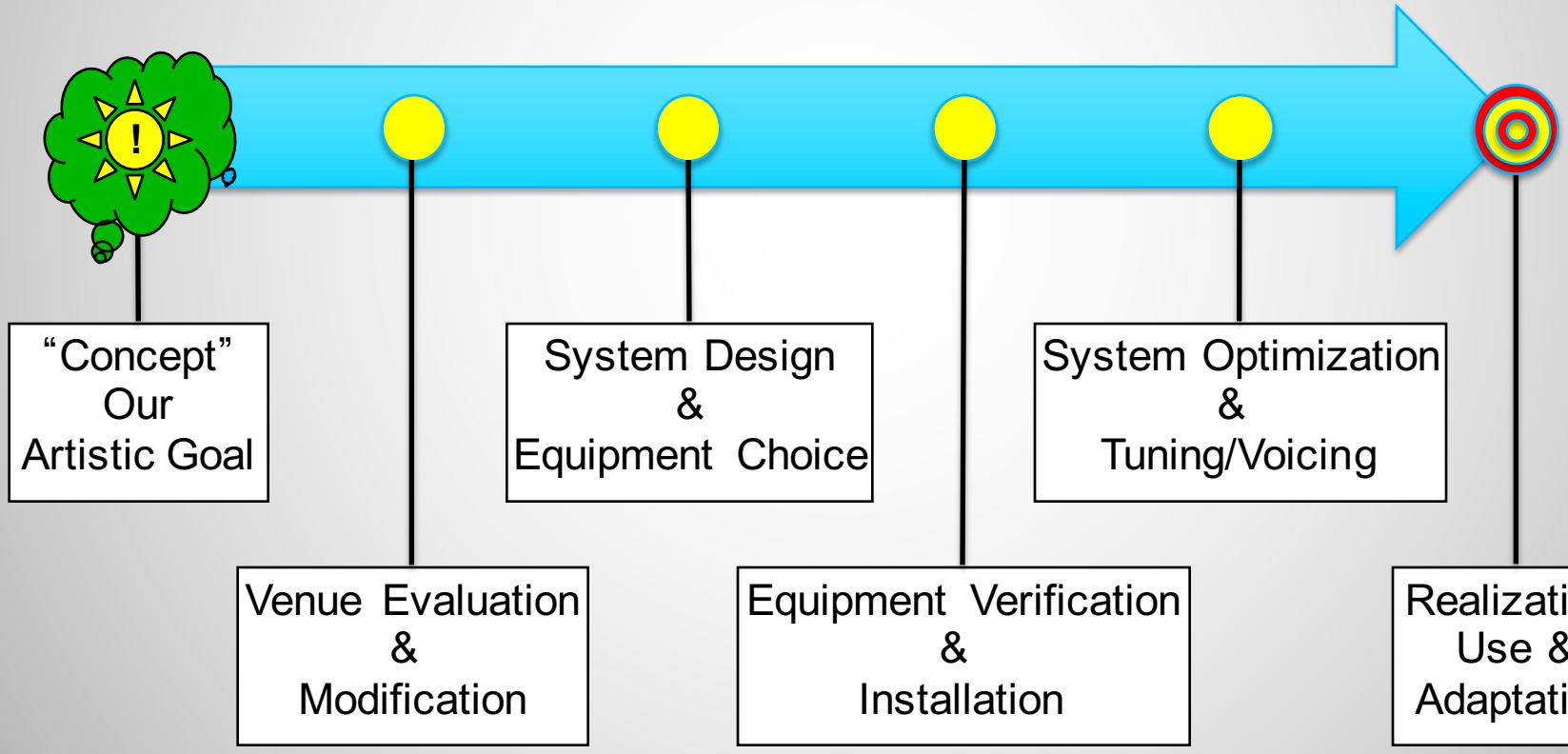
Sound System Alignment

How we get “There” from “Here”



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How Long Does System Tuning / Alignment Take?

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How Long Does System Tuning / Alignment Take?

A: As much time as you have!

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System Alignment:

What decisions/adjustments do we need to make?

and . . .

How **&** **Why** do we make them.

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System Alignment:

"You're just doing that

because it sounds good!"

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System Alignment:

What decisions/adjustments do we need to make?

ReLePT

- **Response**
  - **Coverage & Power**
  - **Frequency Response (Magnitude & Phase)**
  - **Intelligibility, D/R, Transmission Quality**
- **Level**
- **Polarity**
- **Timing**

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System Alignment:

What decisions/adjustments do we need to make?

So . . . DSP/Control-wise, for every sub-system in our sound system, we must set:

1. **EQ**
2. **Level**
3. **Timing**
4. **Polarity**

* Beware the vampire

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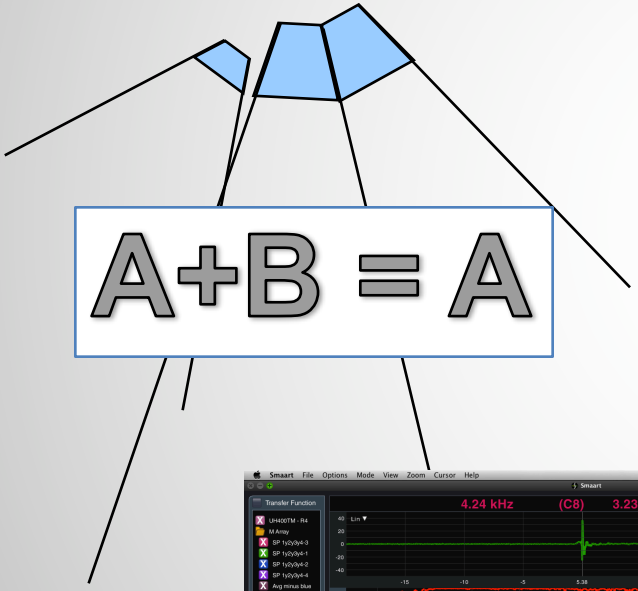
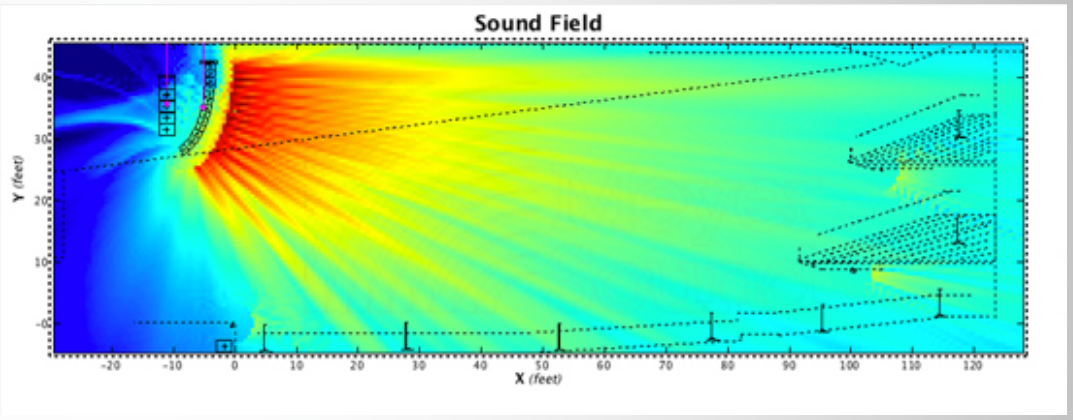
System Alignment:

How & Why do we make our decisions?





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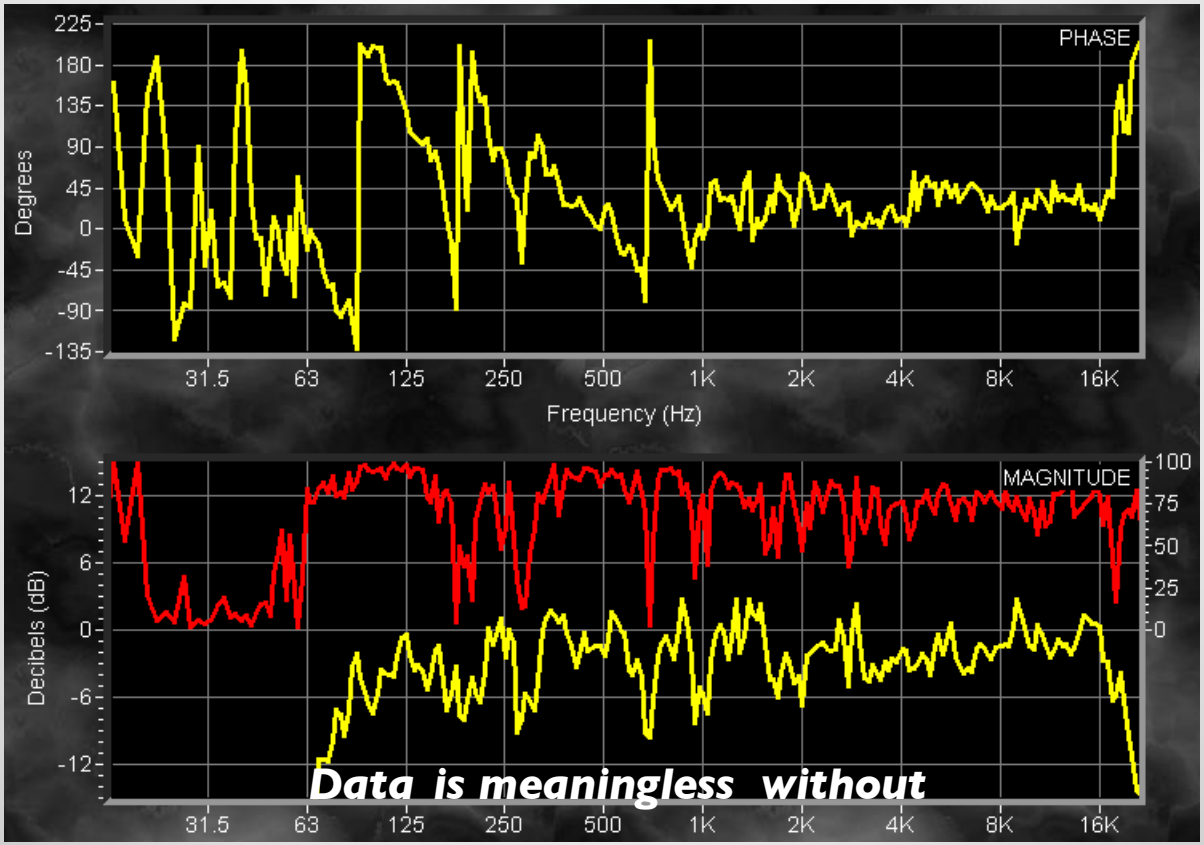
What is wrong with this system? Why doesn't it sound good?



CONTEXT!

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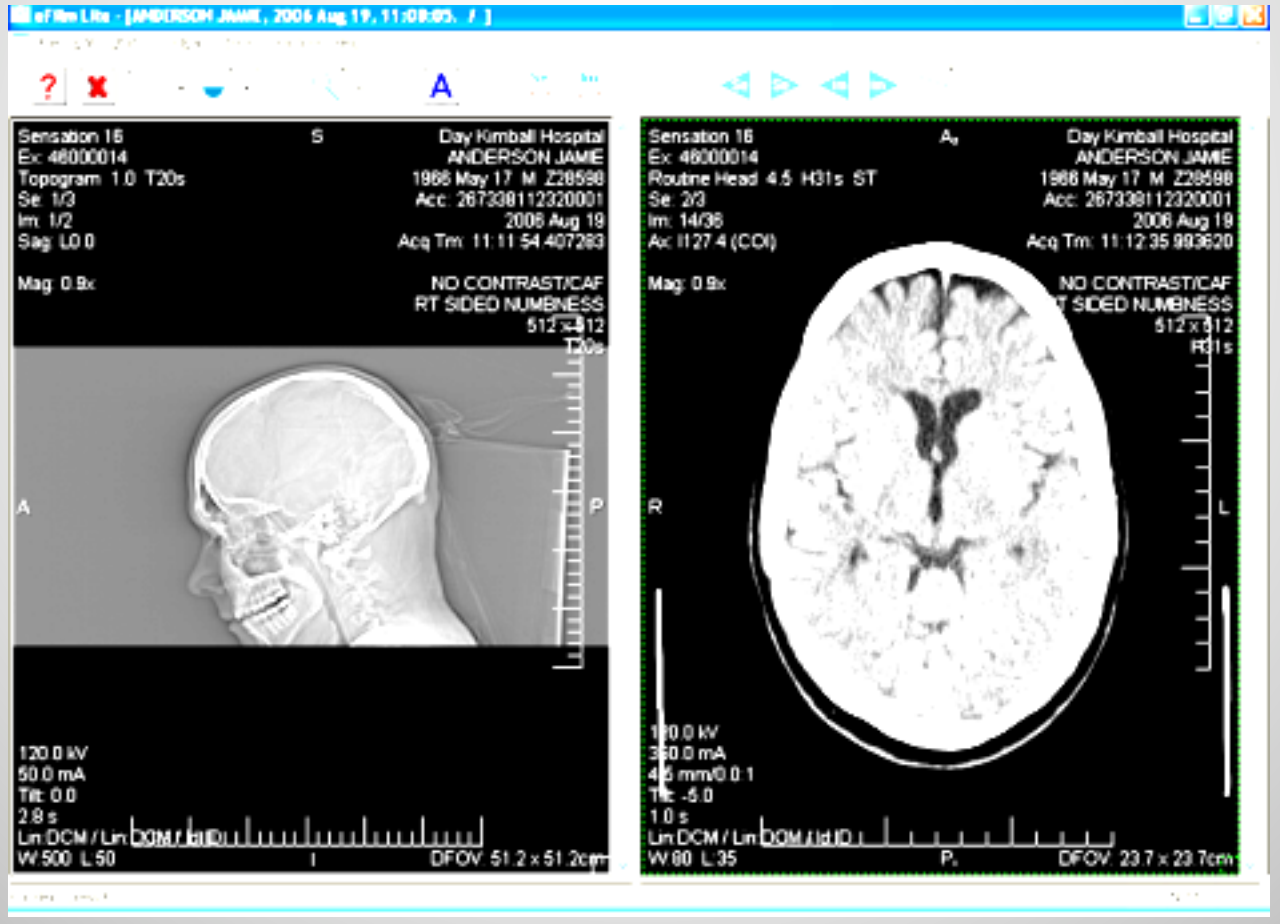
Just Because You Can Operate a CAT Scan . . . Doesn't Make You a Doctor!



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Some Tradeoffs to Keep in Mind

Reinforcement vs. Playback

Tonality vs. Intelligibility

Studio vs. Venue

Simple vs. Perfect

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Context for Using an Analyzer

Purpose

- Aesthetic Goals
- Priorities for my decisions

Process

- Methodology determines success

Perspective

- How tweaky am going to get?
- What are my tolerances?

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System Engineering / Alignment: Goals

- Engineering / System Optimization
  - Proper operation of equipment (Job #1)
  - Consistent coverage
  - Level / Power
- Alignment (Voicing ?)
  - The system alignment needs to fit the goal
    - Tonality
    - Imaging
- Remember - listening is the goal!

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System engineering is managing interactions . . .

. . . with a goal.

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System Engineering / Alignment: Quay Koncepts

Systems Interact Most Where They are Equal Level

Solve the Problem at the Source

Use the Right Tool

20% / 80%

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Systems Interact Most Where They Are Equal Level

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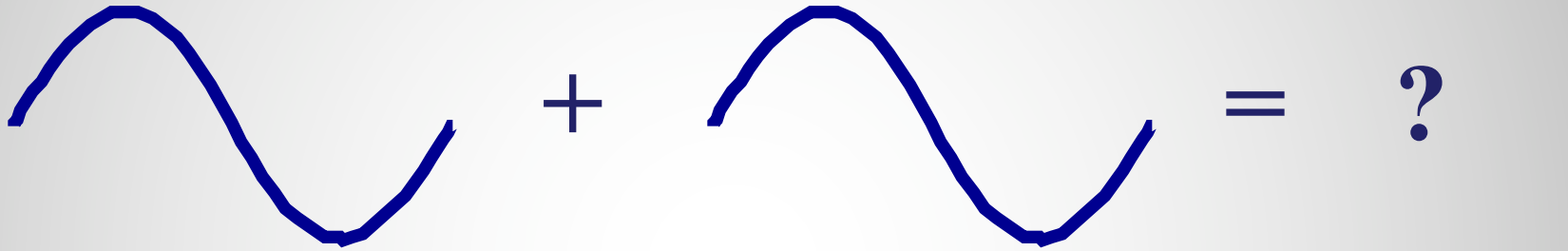
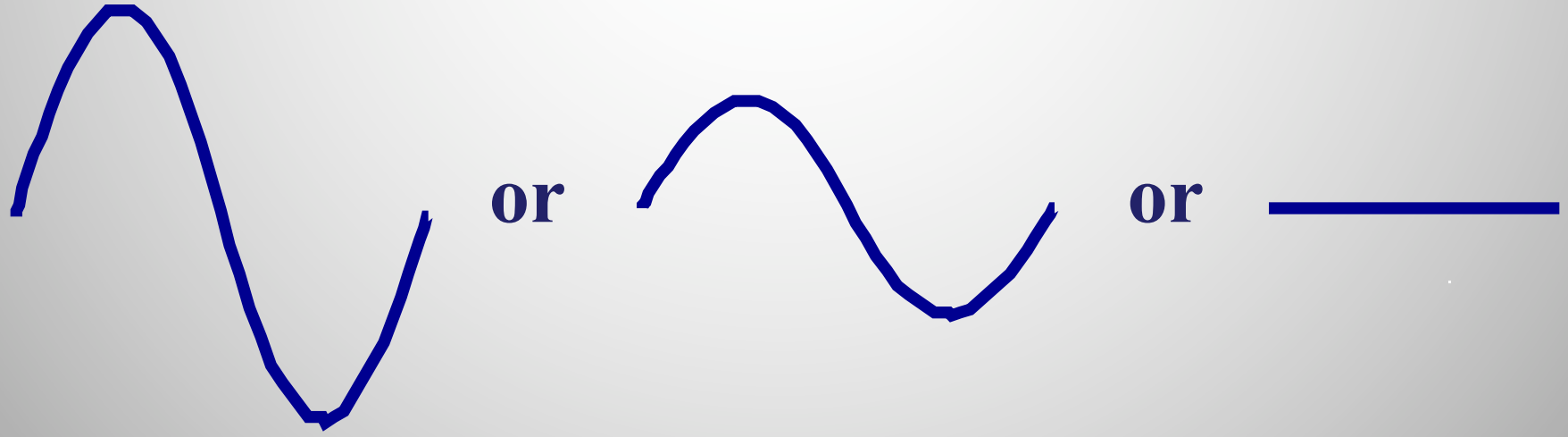
Managing Interactions: The Big Question





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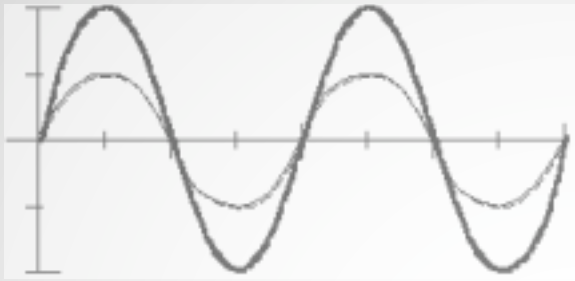
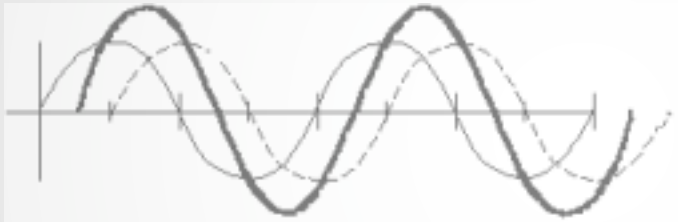
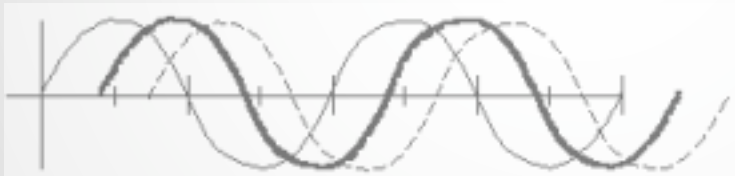
Addition of Sine Waves of Same Frequency and Equal Amplitude



Φ = 0 Degrees
Complete Addition

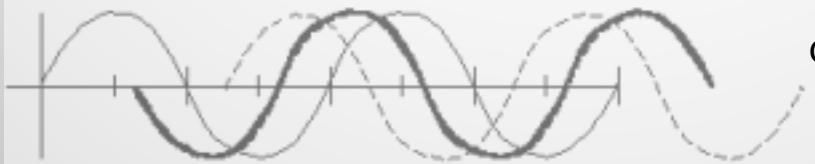


Φ = 90 Degrees
Partial Addition



Φ = 120 Degrees
No Addition

Φ = 180 Degrees
Complete Cancellation



Φ = 240 Degrees
No Addition

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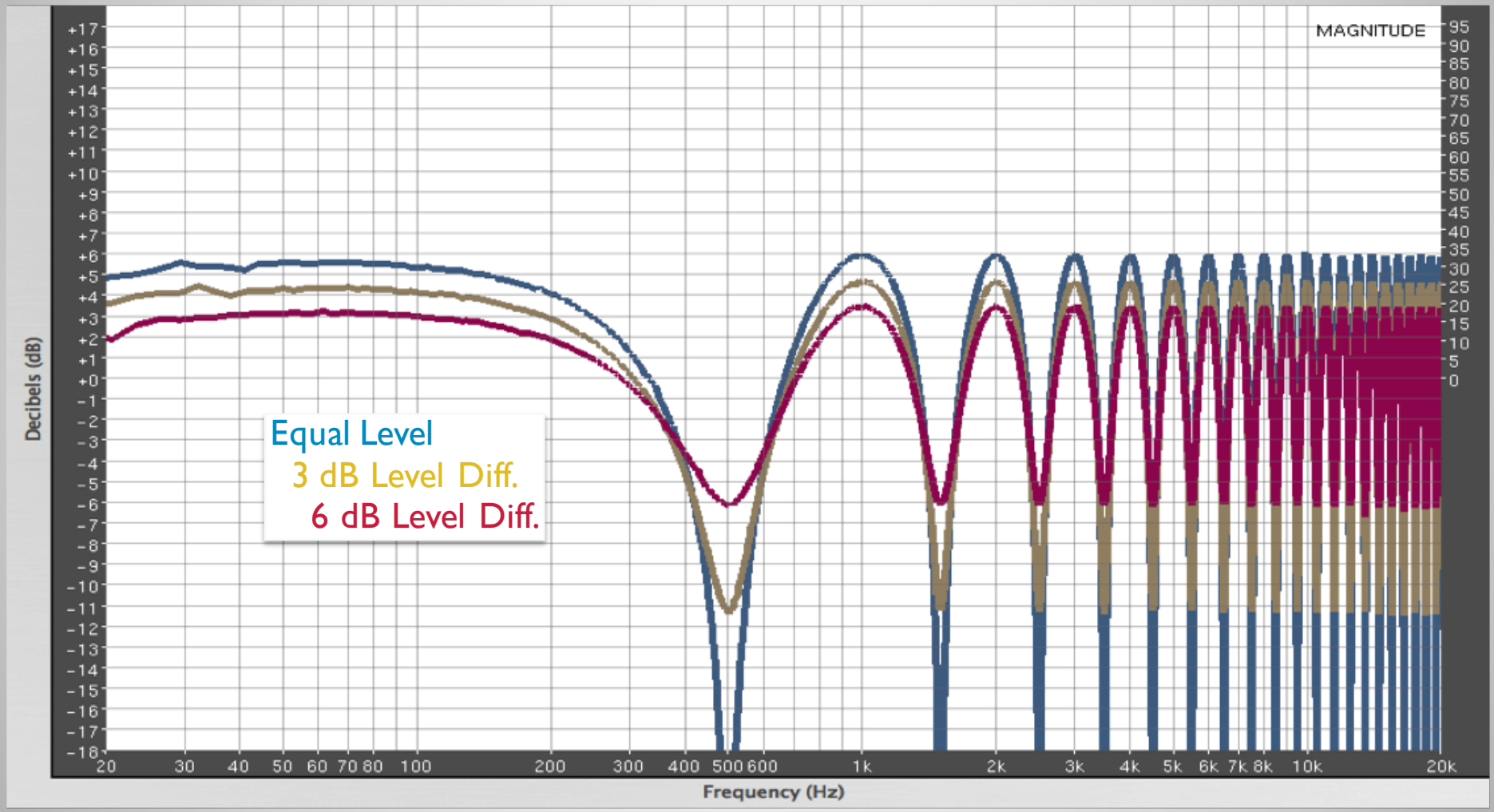
1 kHz Comb Filters:

Addition of Signals of Varying Relative Level



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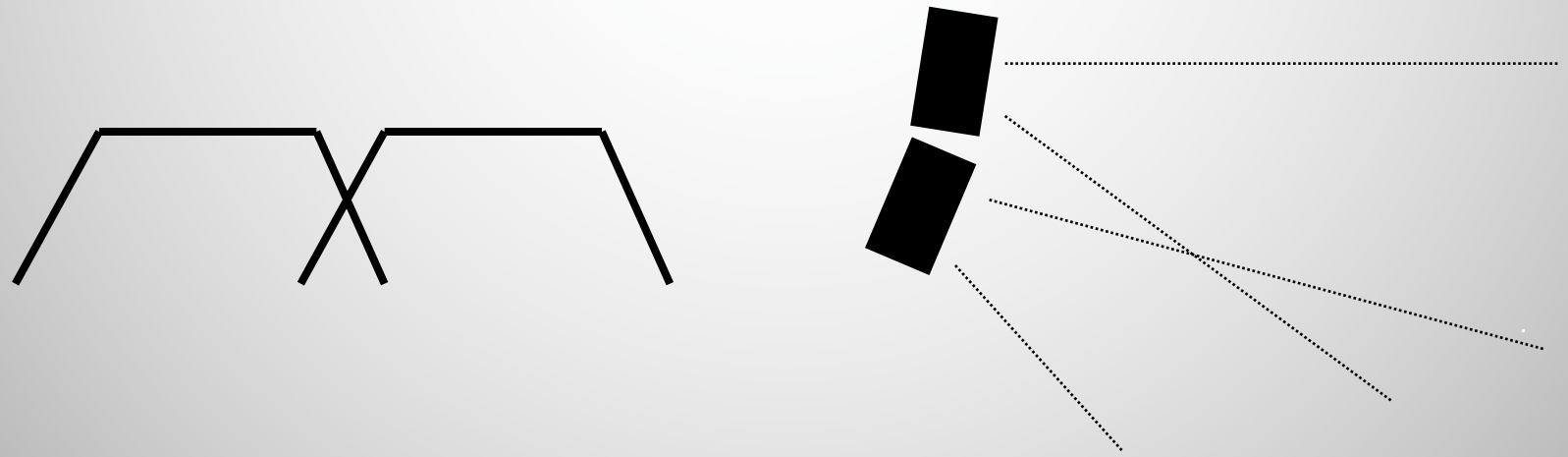
System Engineering Key Concept:

- Interactions are greatest where signals are equal level - *Crossover Points*



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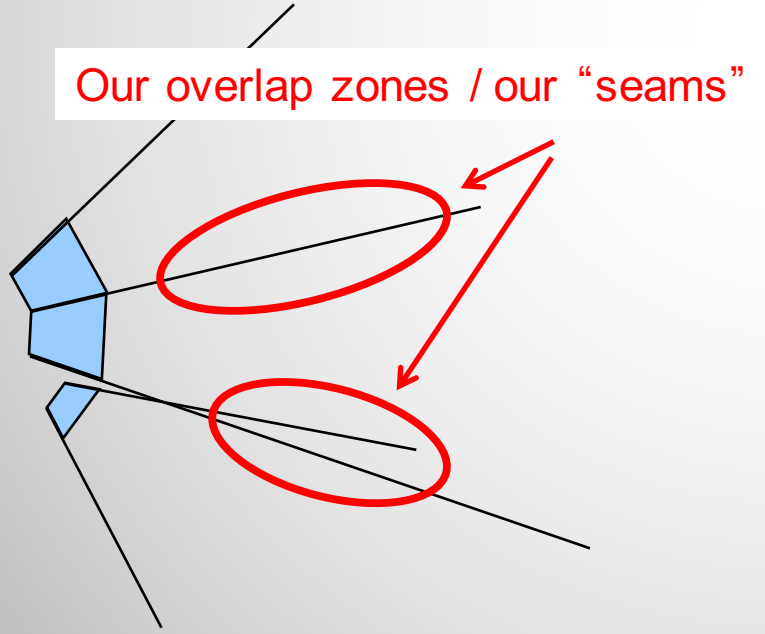
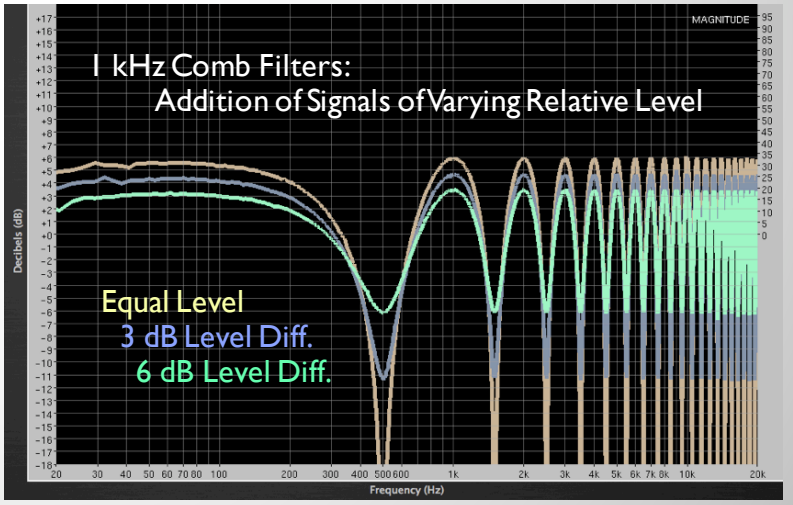
Our System Engineering Key Concepts

Systems Interact Most Where They Are Equal Level





Relative level of systems determines location of equal level seams.

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System Engineering Key Concept:

- Interactions are greatest where signals are equal level - *Crossover Points*
  - *Relative phase governs the interaction*
    - *Phase Shift (Filters)*
    - *Polarity (Wiring)*
    - *Delay (Time Alignment)*
      - Relative Level & Phase is KEY!!!!!!!!

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Solve the Problem at the Source

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System Engineering Key Concepts:

- Solve problem at source

  –*The closer to the source . . .*
  the more effective the solution.

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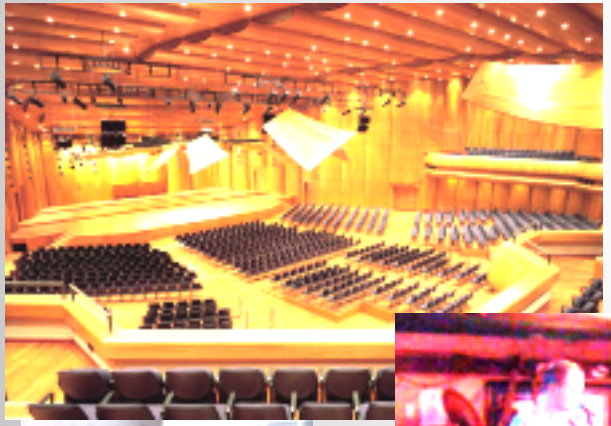
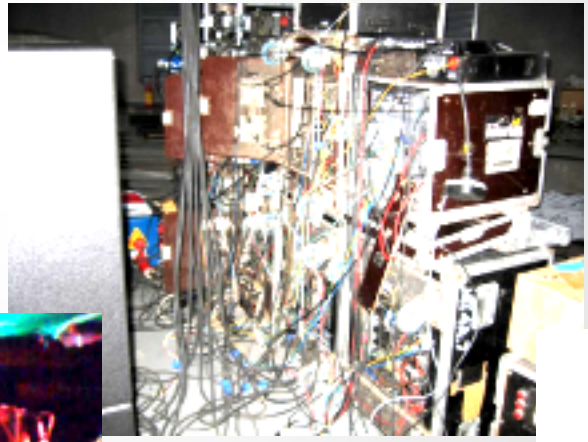
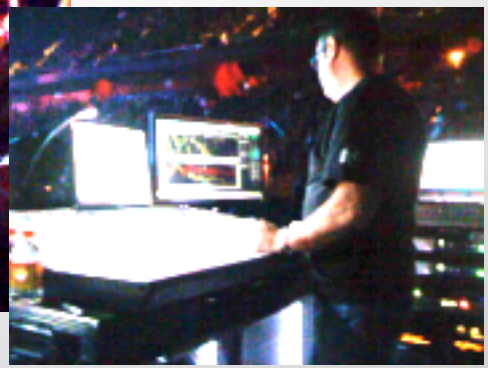
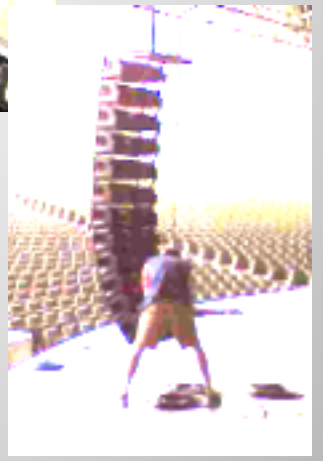
Solve the Problem at the Source

The closer to the source . . .
the more effective the solution









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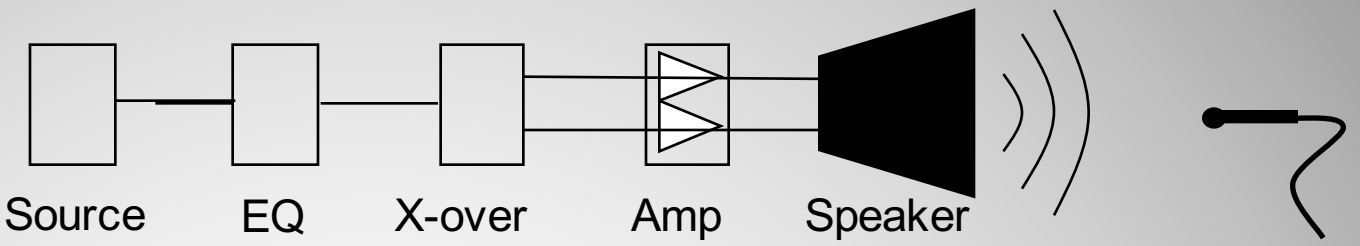
Example:

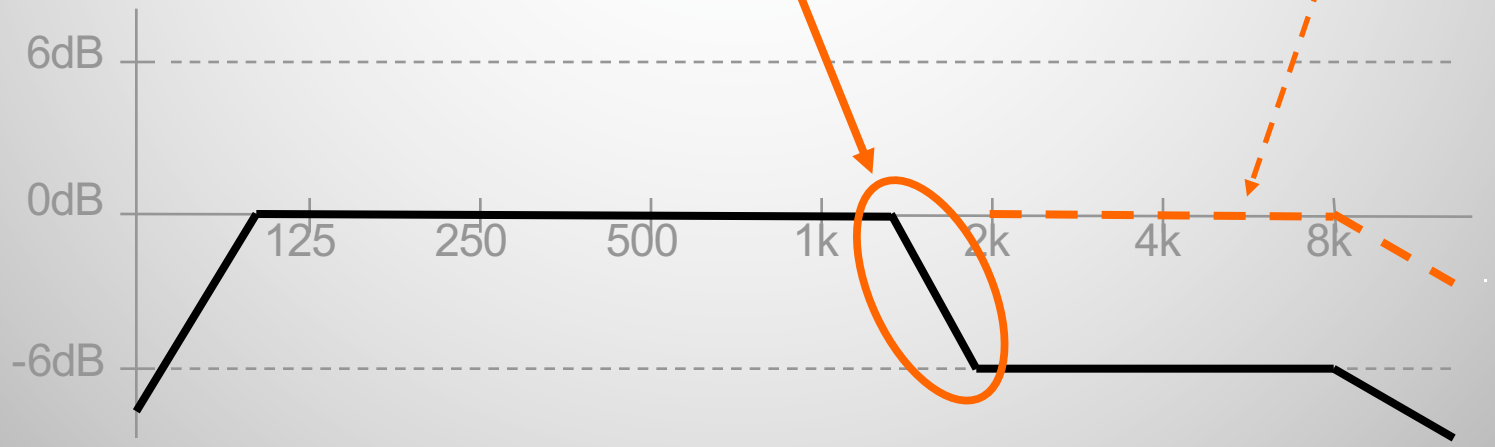


The speaker you are measuring has a relatively flat response except:

HF is 6 dB lower than LF above 1.6 kHz

Substantial HF noise

Target response: nominally flat



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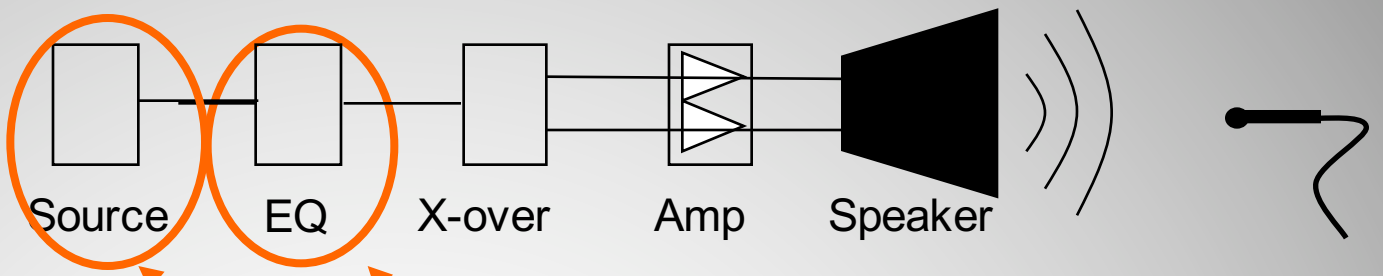
Example:



The speaker you are measuring has a relatively flat response except:

HF is 6 dB lower than LF above 1.6 kHz

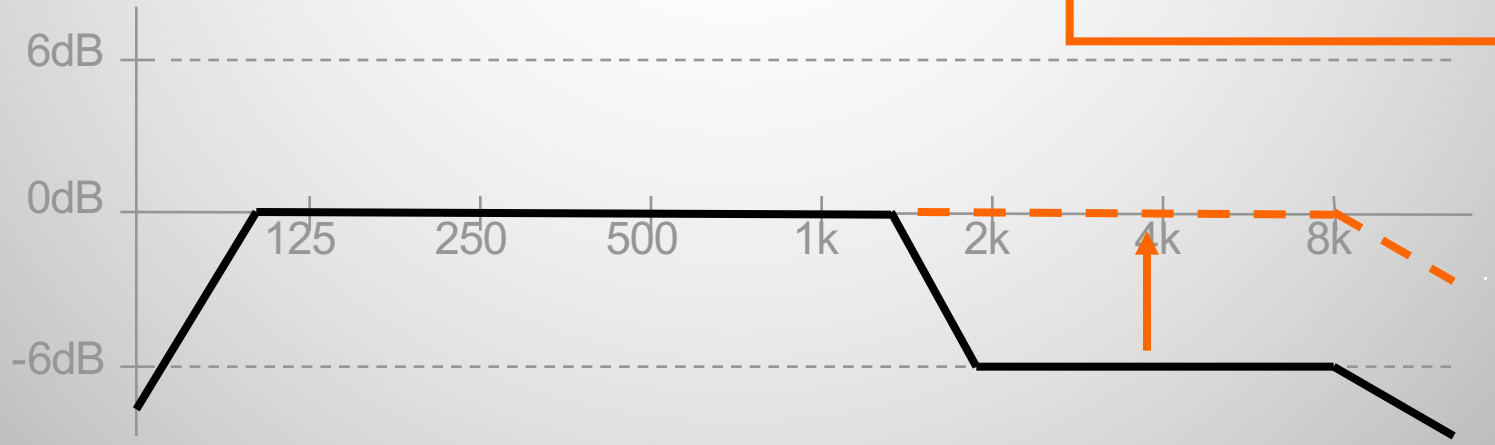
Substantial HF noise

Potential Solutions

EQ:

Bring up HF on EQ

Add extra HF to program material



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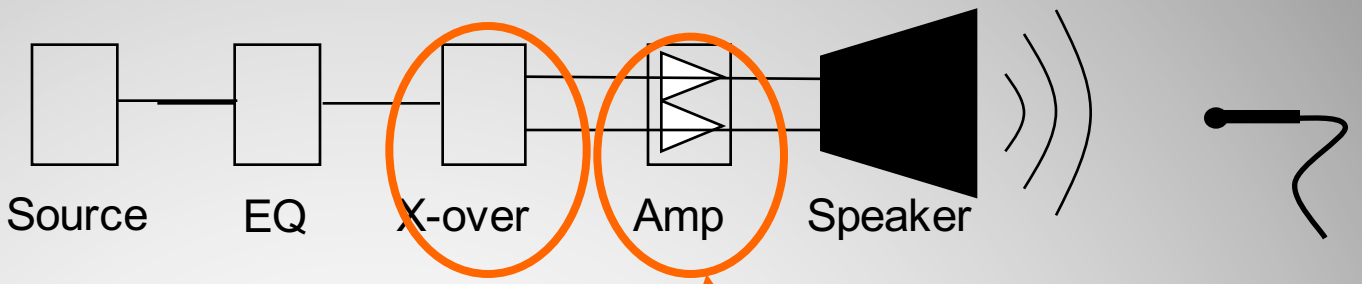


The speaker you are measuring has a relatively flat response except:

HF is 6 dB lower than LF above 1.6 kHz

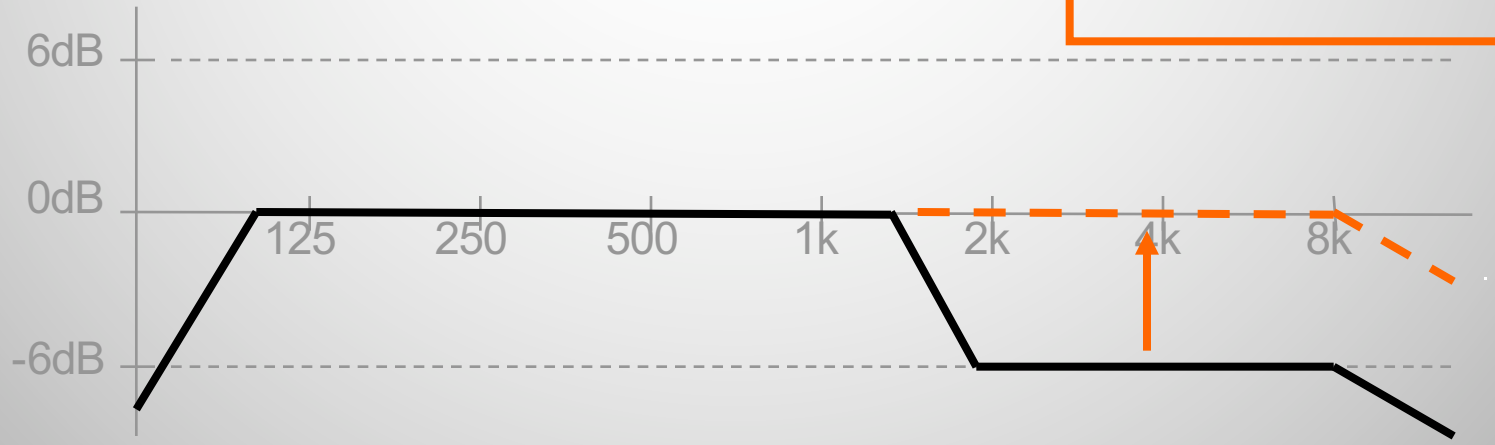
Substantial HF noise

Potential Solutions

Level:

Turn up HF on Amp

Turn up HF at X-over output



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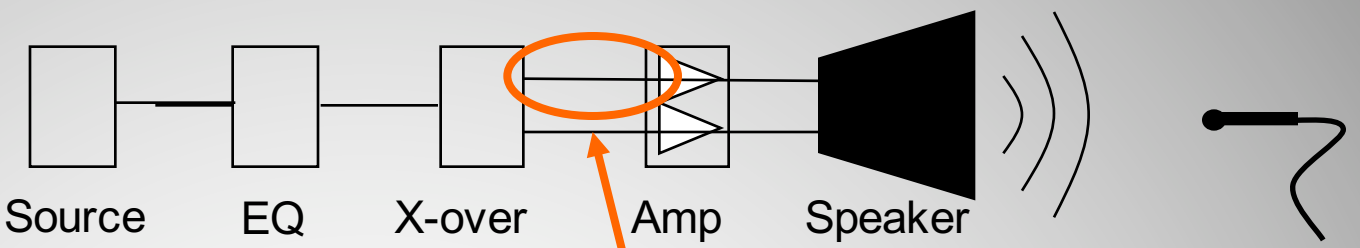


The speaker you are measuring has a relatively flat response except:

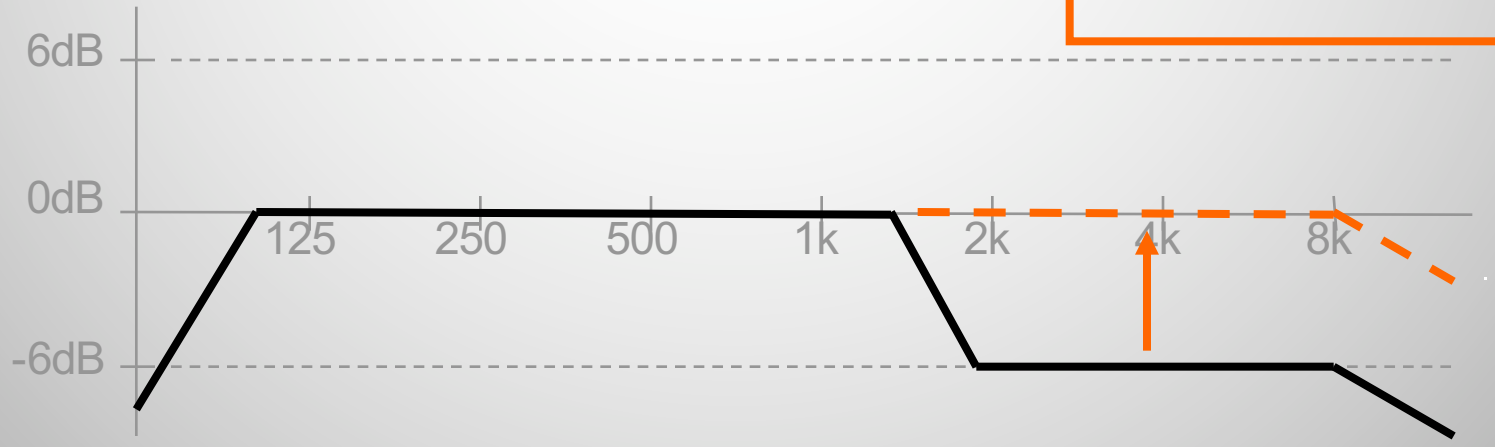
HF is 6 dB lower than LF above 1.6 kHz

Substantial HF noise

Potential Solutions

System Maintenance:

Loss of 6 dB and in crease in HF noise a good indication of a bad cable on X-over HF out.



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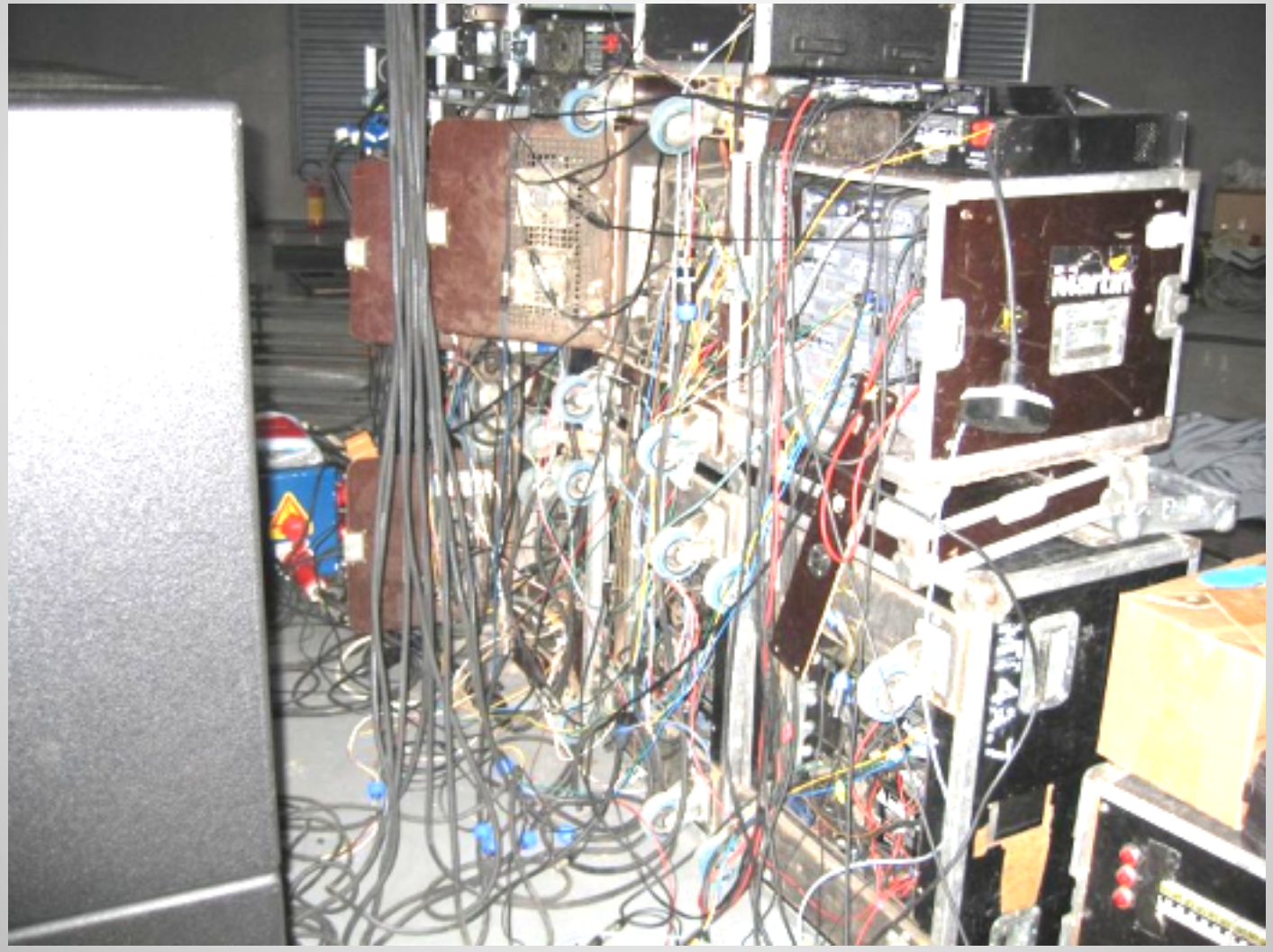
One Bad Cable . . .



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Use the Right Tool

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System Engineering Key Concepts:

- Use the right tool

  – *"Every item in your tool box is a hammer . . . except your wood chisels, they're screwdrivers."*

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Tools in Order of Use

1

- Acoustic Design /Treatment
- Equipment Choice / Maintenance
- System Design - *"Design to align"*

2

- Level
- Delay / Timing

3

- And lastly . . . EQ

Don't assume the solution - determine the problem, then choose your best tool

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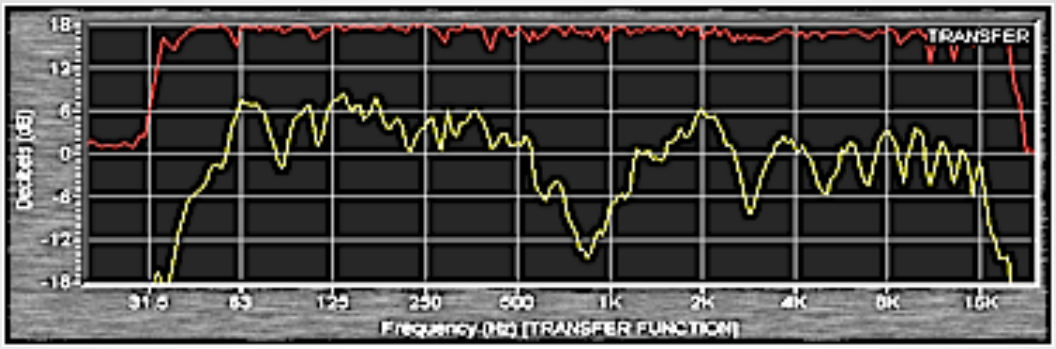

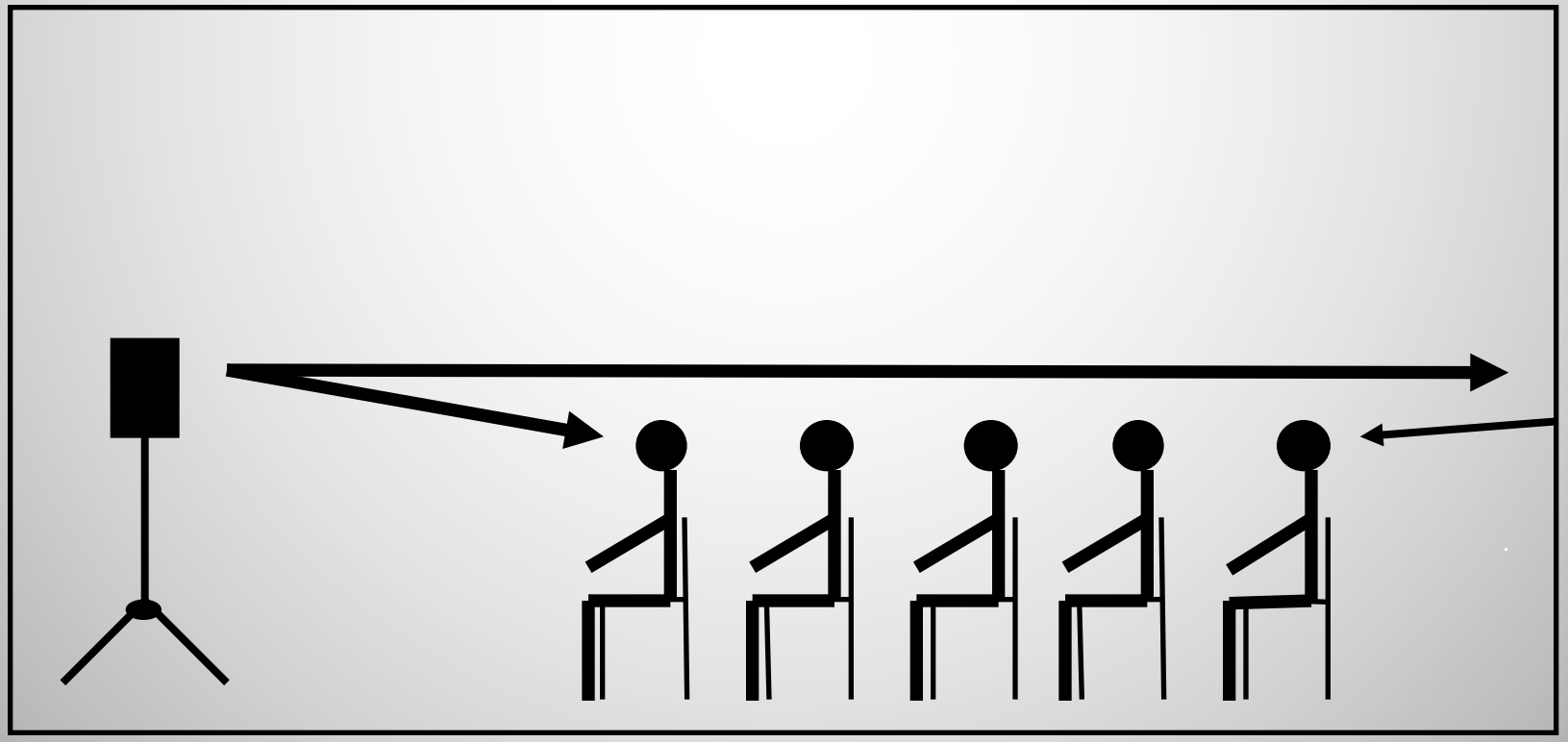

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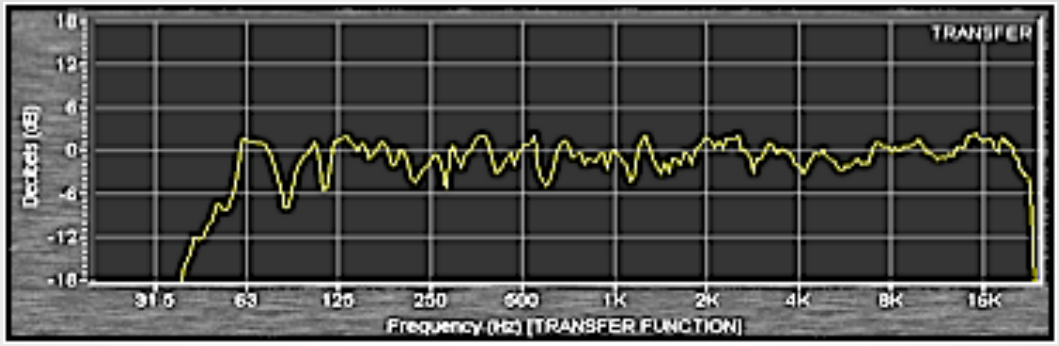
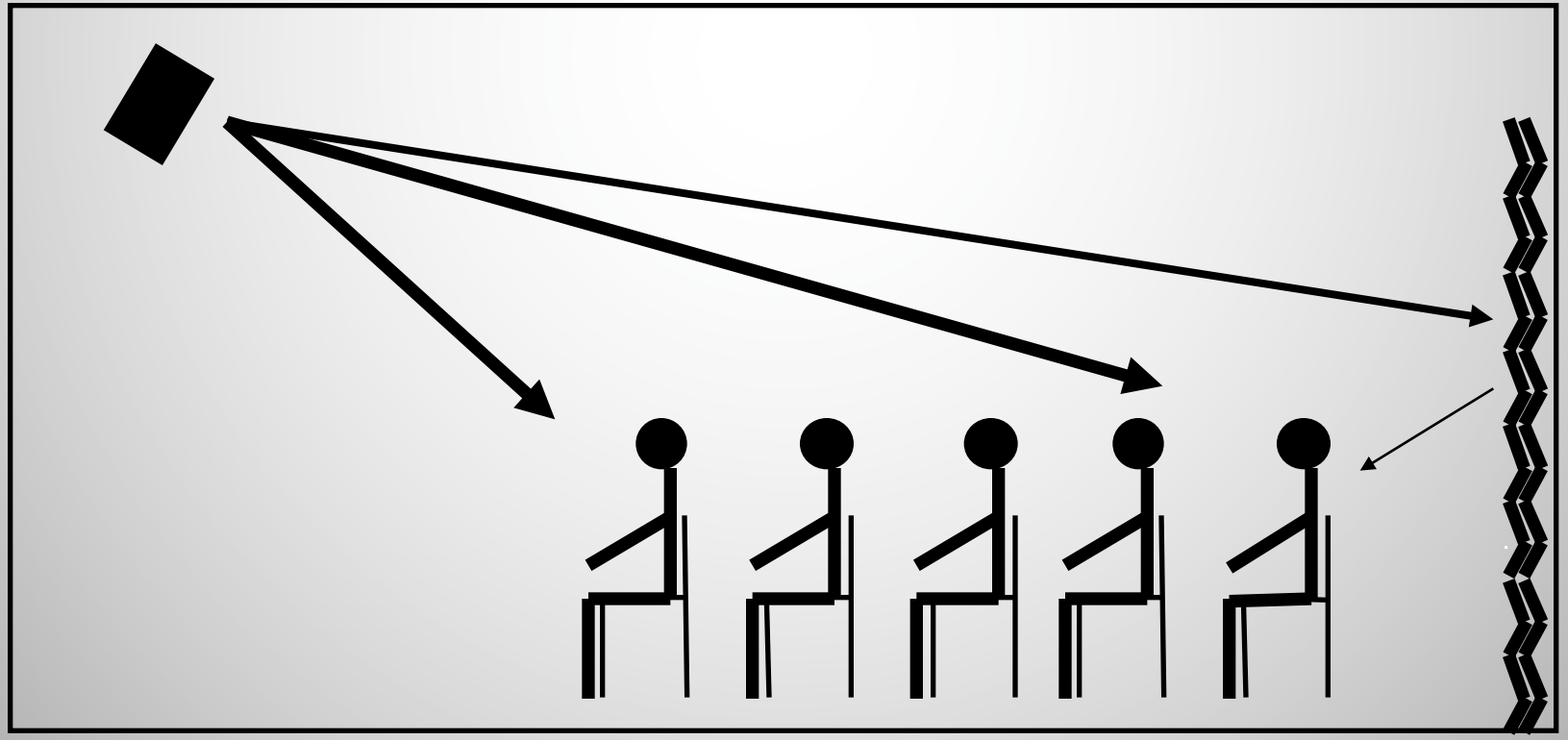
Solution(s)





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Our goal is to fix our system . . .

. . . not the trace on the screen!

Smaart is NOT a video game!

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System Engineering
&
The Serenity Prayer . . .

Grant me the Serenity
To accept the things I cannot change…

Courage to change the things I can,

And Wisdom to know the difference.

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Or Alternatively. . .

Primum non nocere

(First, do no harm)

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System Alignment & Smaart

System Alignment:

Is a Series of Decisions Made in Context

It is Optimizing Your Compromises

Smaart:

Is an Analyzer . . . Is a ***Tool***

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An analyzer is only a ***tool***: ***YOU*** make the decisions

You decide what to measure.

You decide which measurements to use.

You decide what the resulting data means.

And you decide what to do about it.

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System Alignment

"Smaart-ing" a System

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Any idiot can get squiggly line on the Smaart screen.

Our goal is to take measurements we can make decisions on.

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To Get Useful Measurements We Must:

1. ***Verify that we are making our measurements properly.***

2. ***Verify that it is an appropriate measurement for our purpose.***

How Can We Make Good Decisions Off of Bad Measurements?

How Can We Get Actionable Data?

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Mic Position

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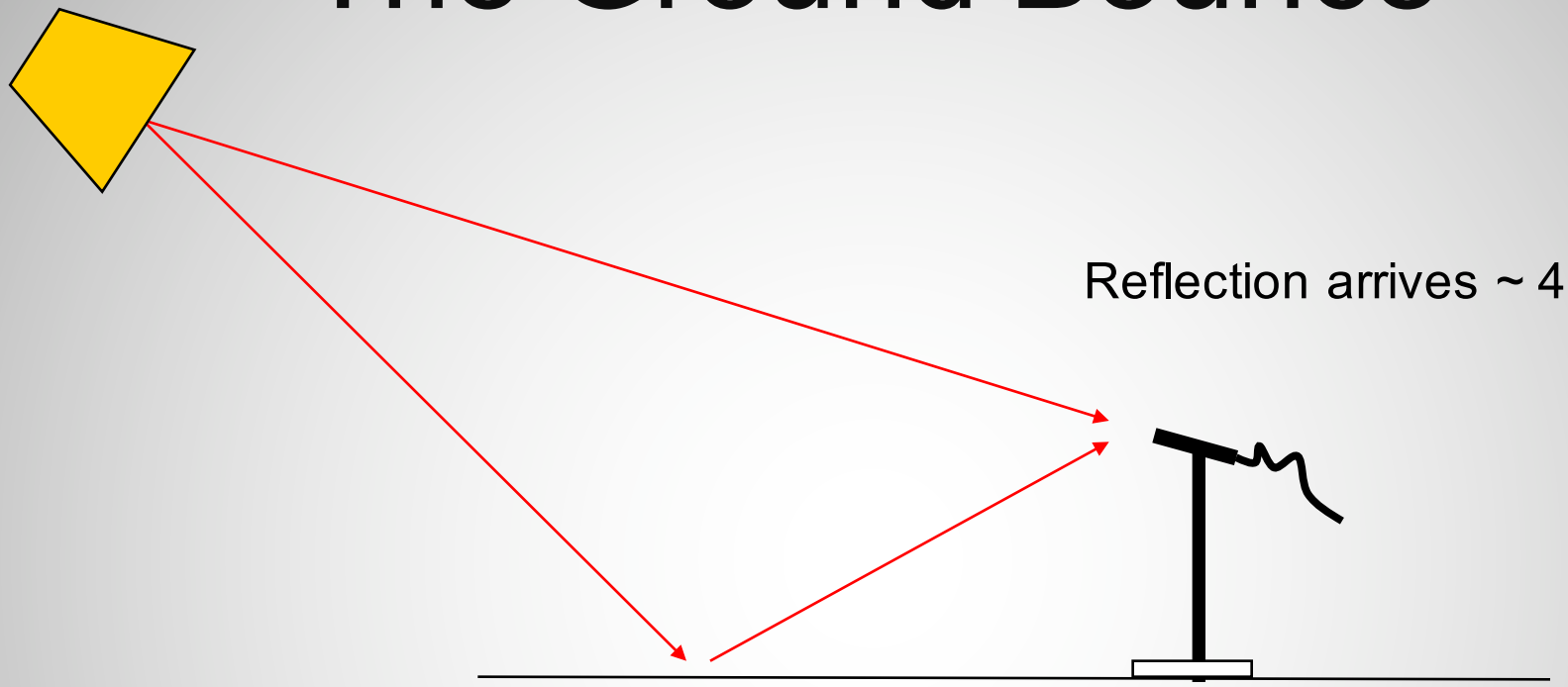
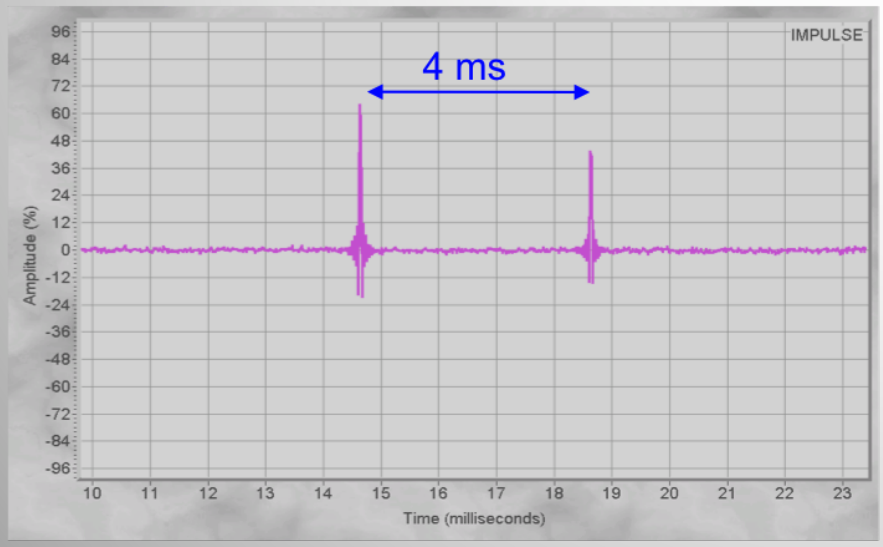
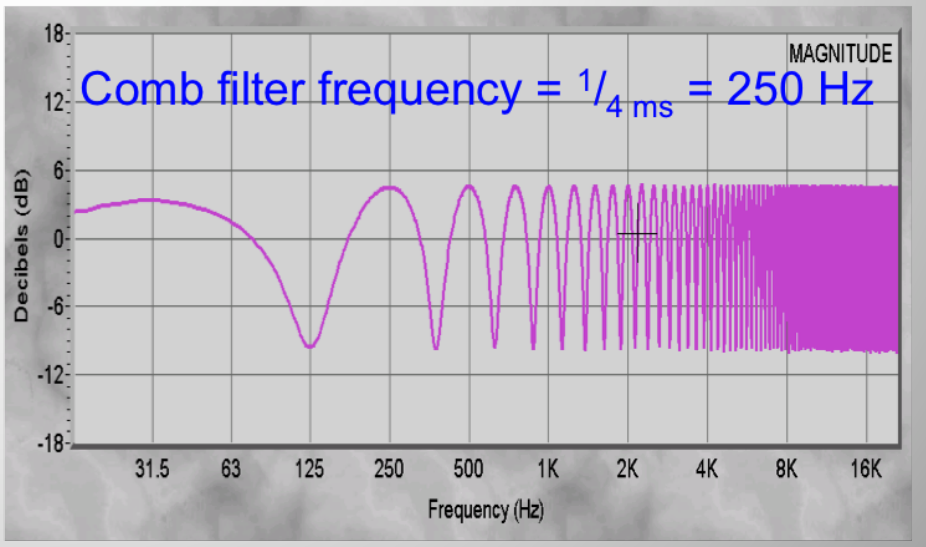
The Ground Bounce



Reflection arrives ~ 4 ms





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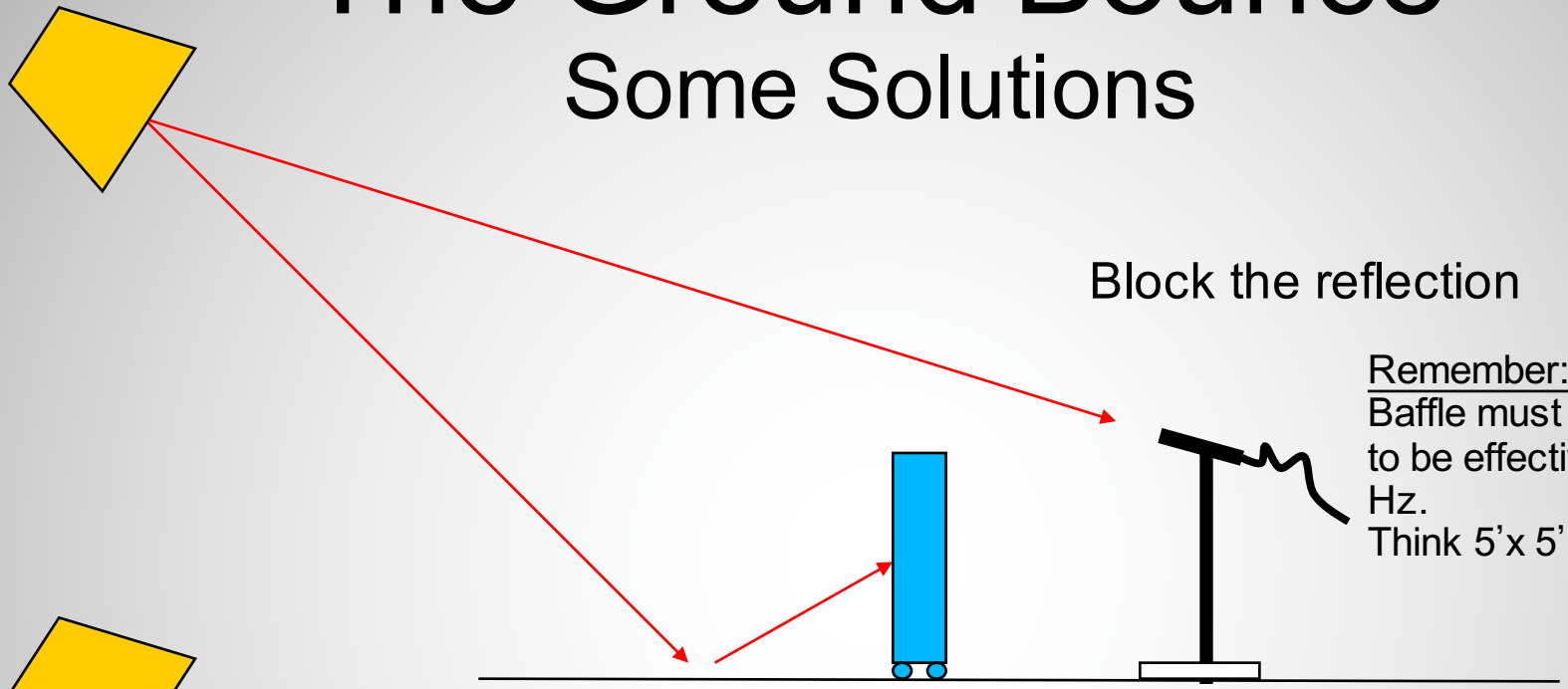
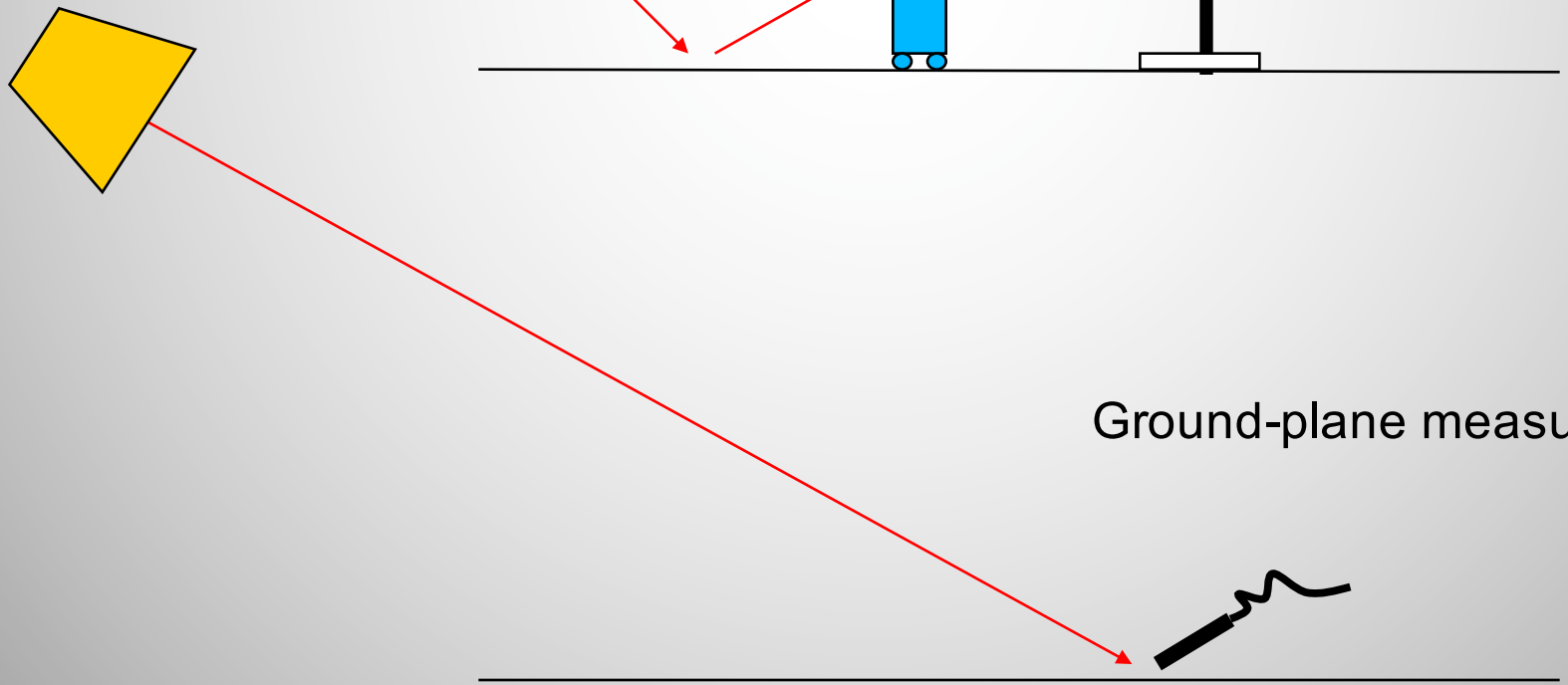
The Ground Bounce

Some Solutions



Block the reflection

Remember:
Baffle must be large enough to be effective above 100 Hz.
Think 5'x 5' (1.5 m x 1.5 m)



Ground-plane measurement

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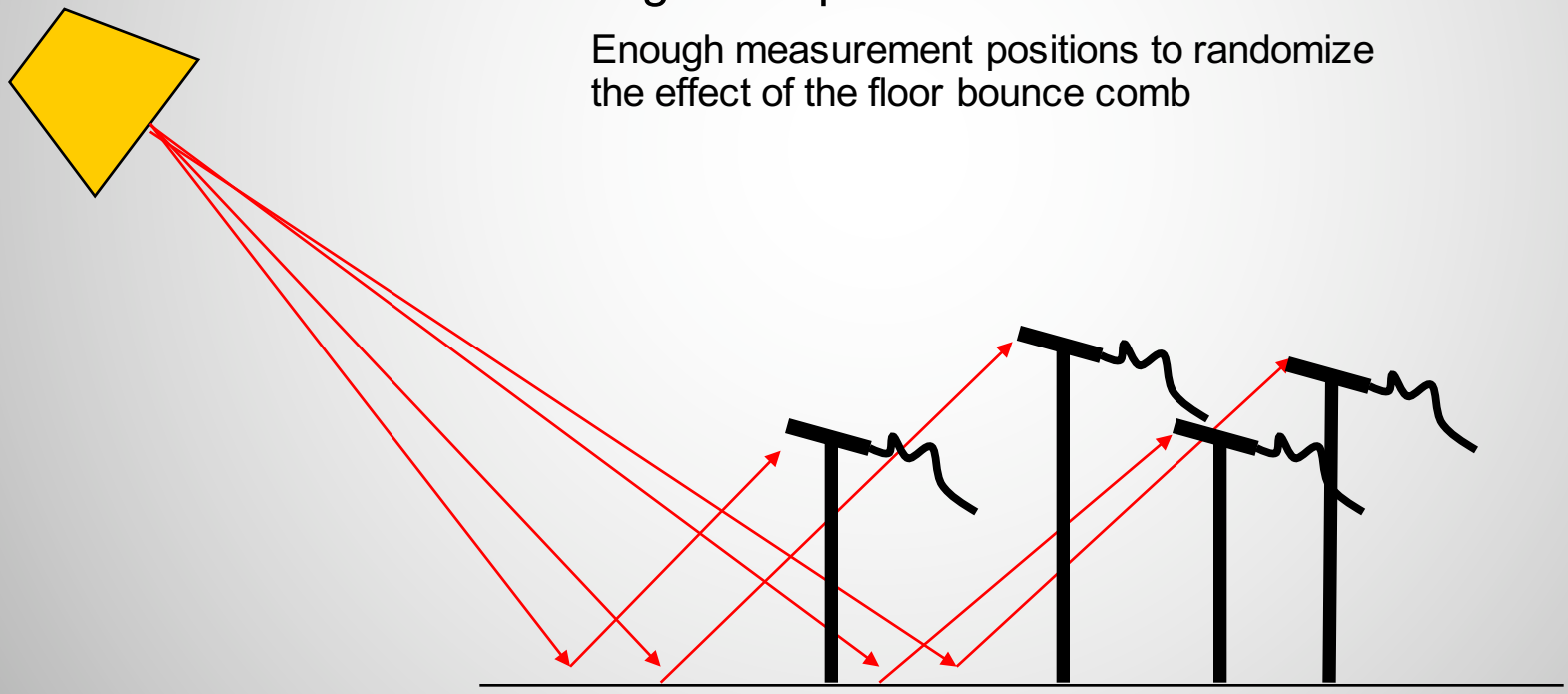
The Ground Bounce
Some Solutions

Average Multiple Measurements

Enough measurement positions to randomize the effect of the floor bounce comb



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Mic Position

What are we trying to determine?

What are our decision points

– our system pressure points ?

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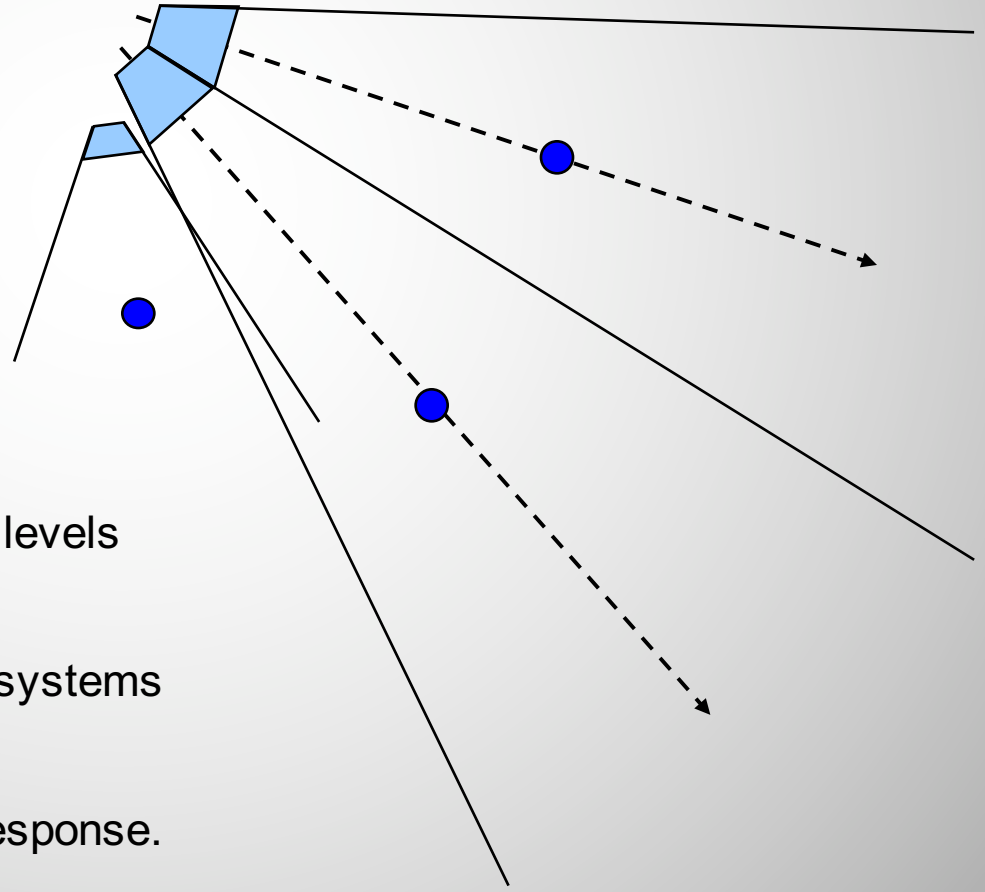
Microphone Positions

Type 1 (Primary):

- Our primary reference point for this speaker/array
- Used as a single, "representative" position.
- Used for setting relative system levels
- Used for setting timing of delay systems
- Used for determining average response.



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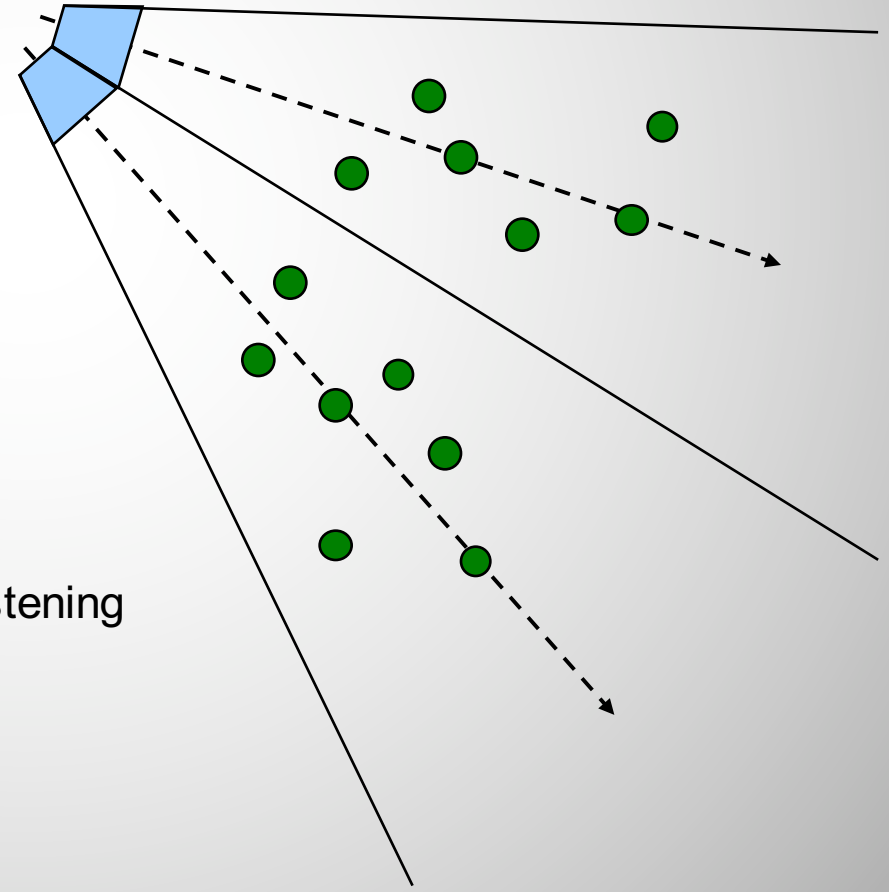
Microphone Positions

Type 2 (Secondary):



- Used to determine average response (spatial averaging)
- Can be found by simple process of listening for consistency

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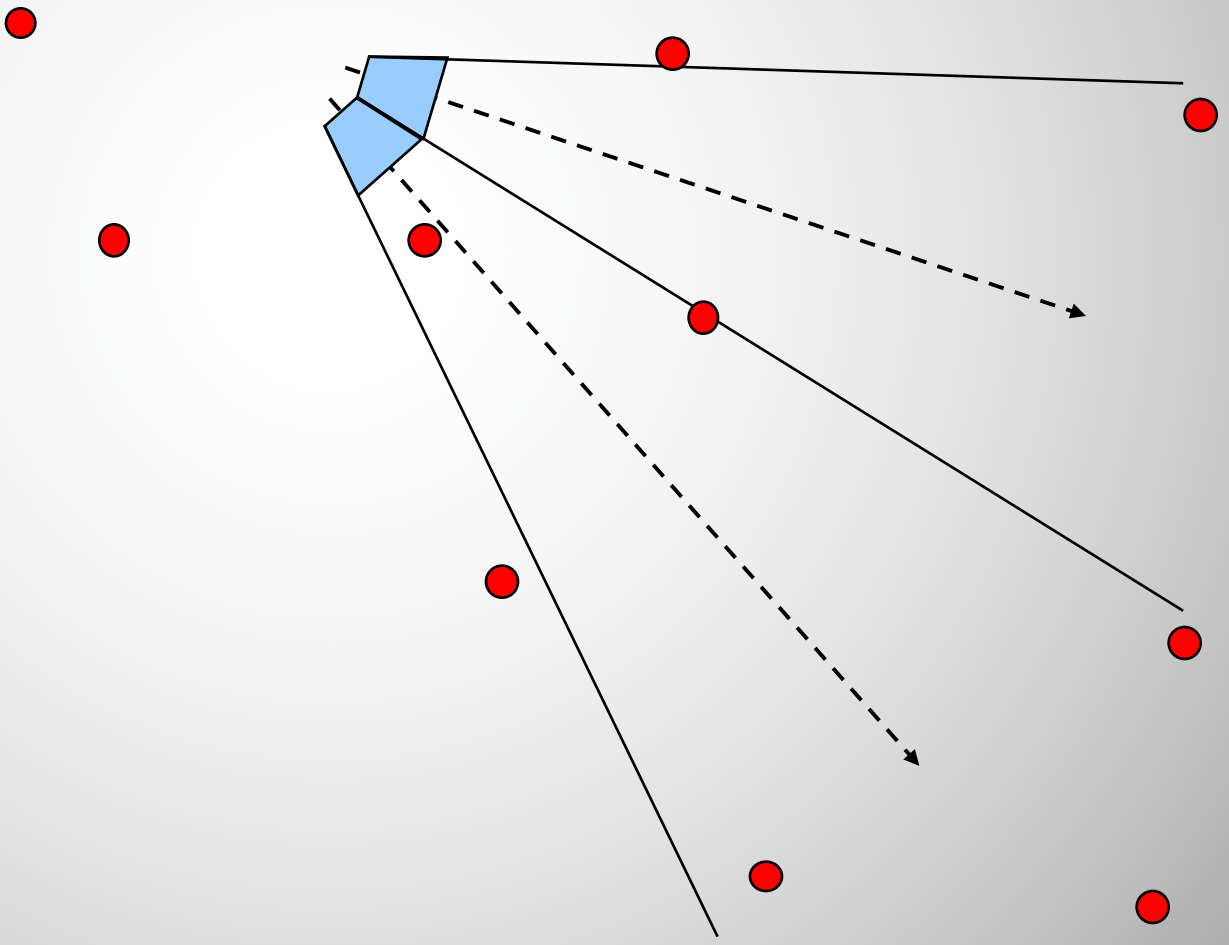
Microphone Positions

Type 3 (Tertiary):



Used for investigation

- Near field
- Side lobes
- Seam Timings

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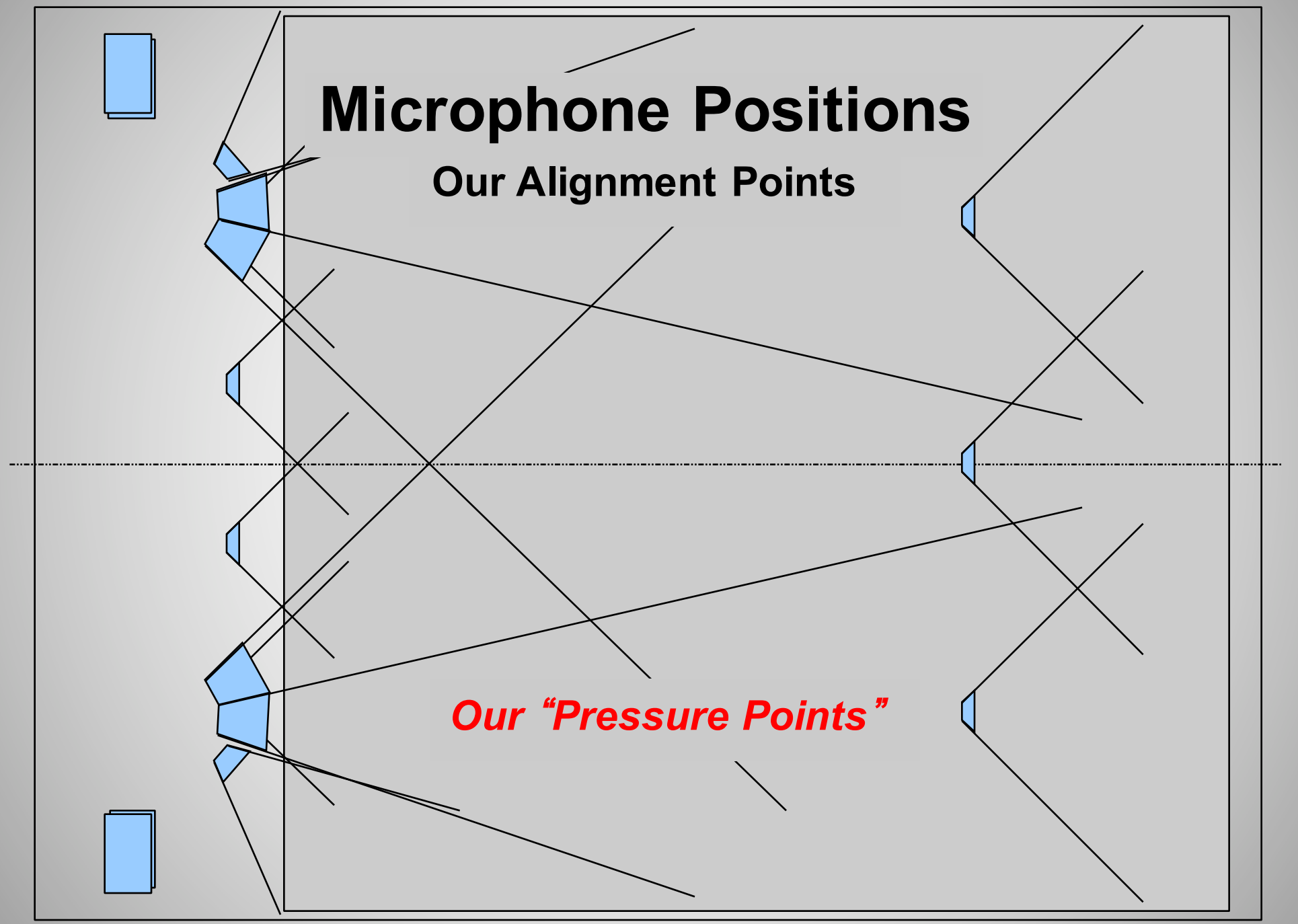

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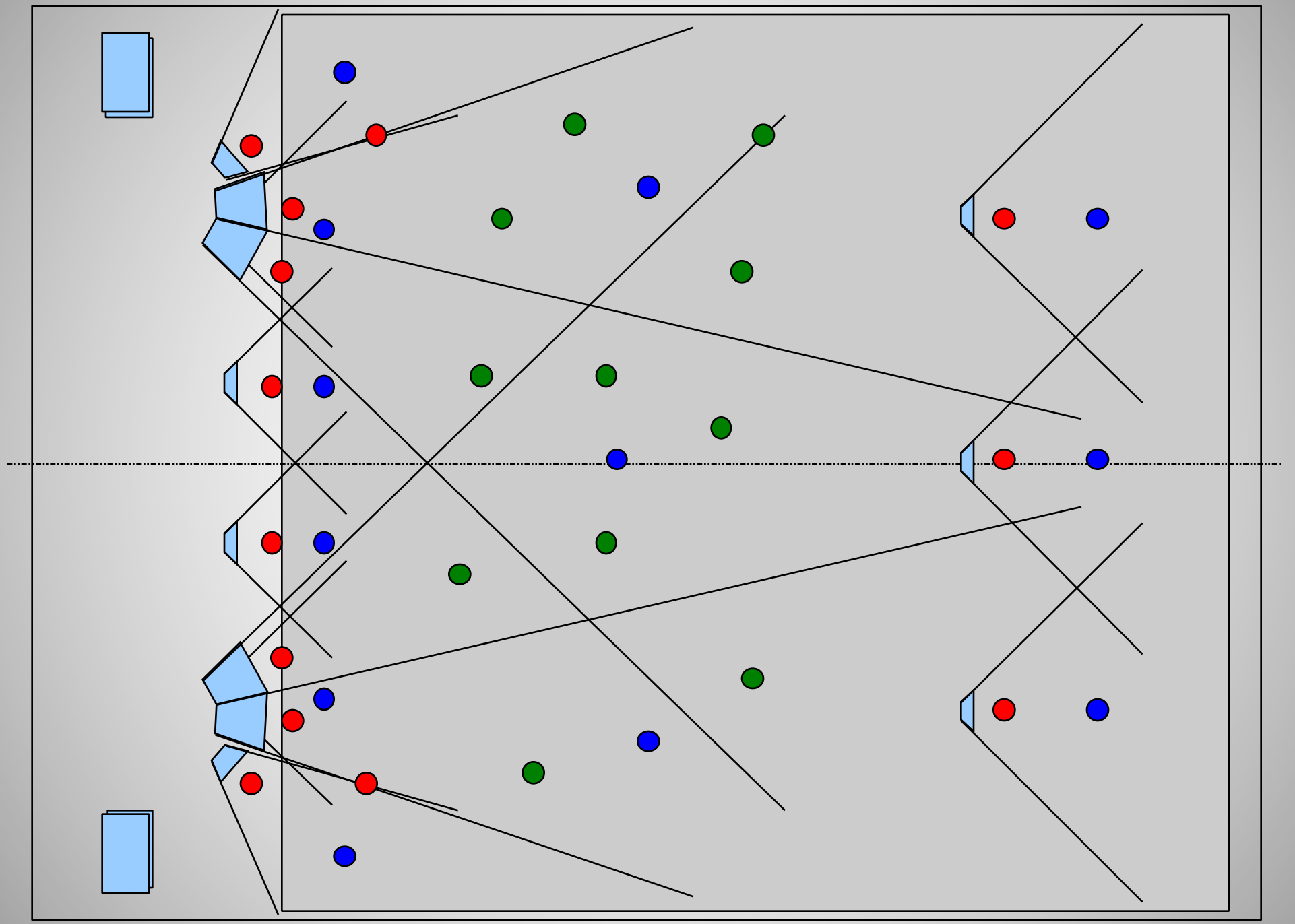

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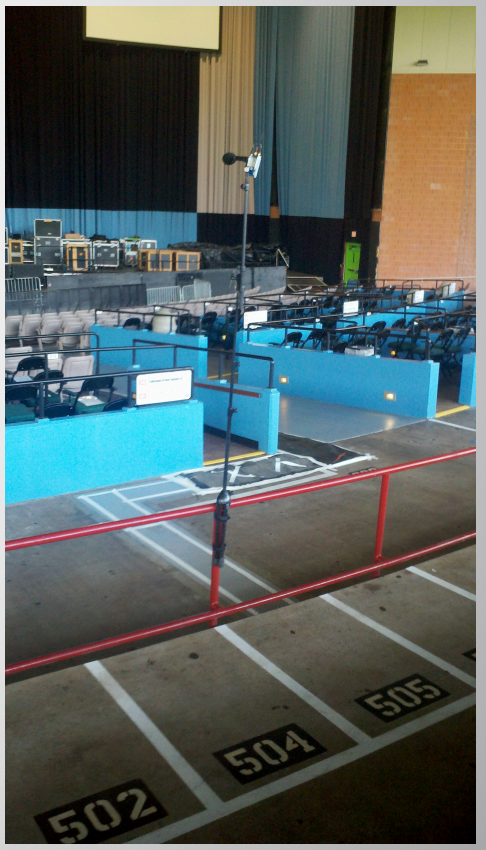
Measurement Microphones



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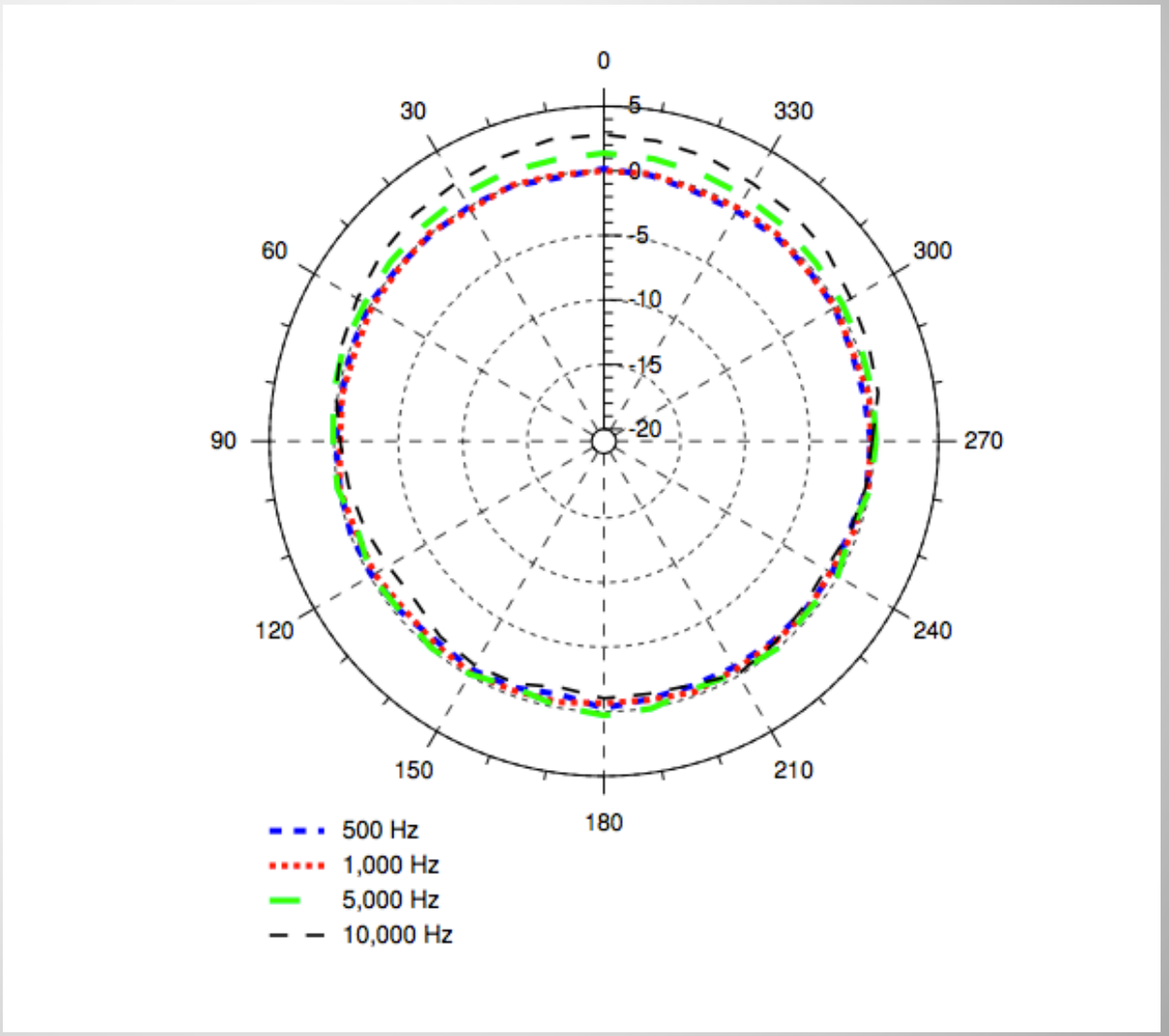
Measurement Microphones

Free-Field
vs.
Diffuse Field
Omni-Directional

&

Our Friend
“Congestion”



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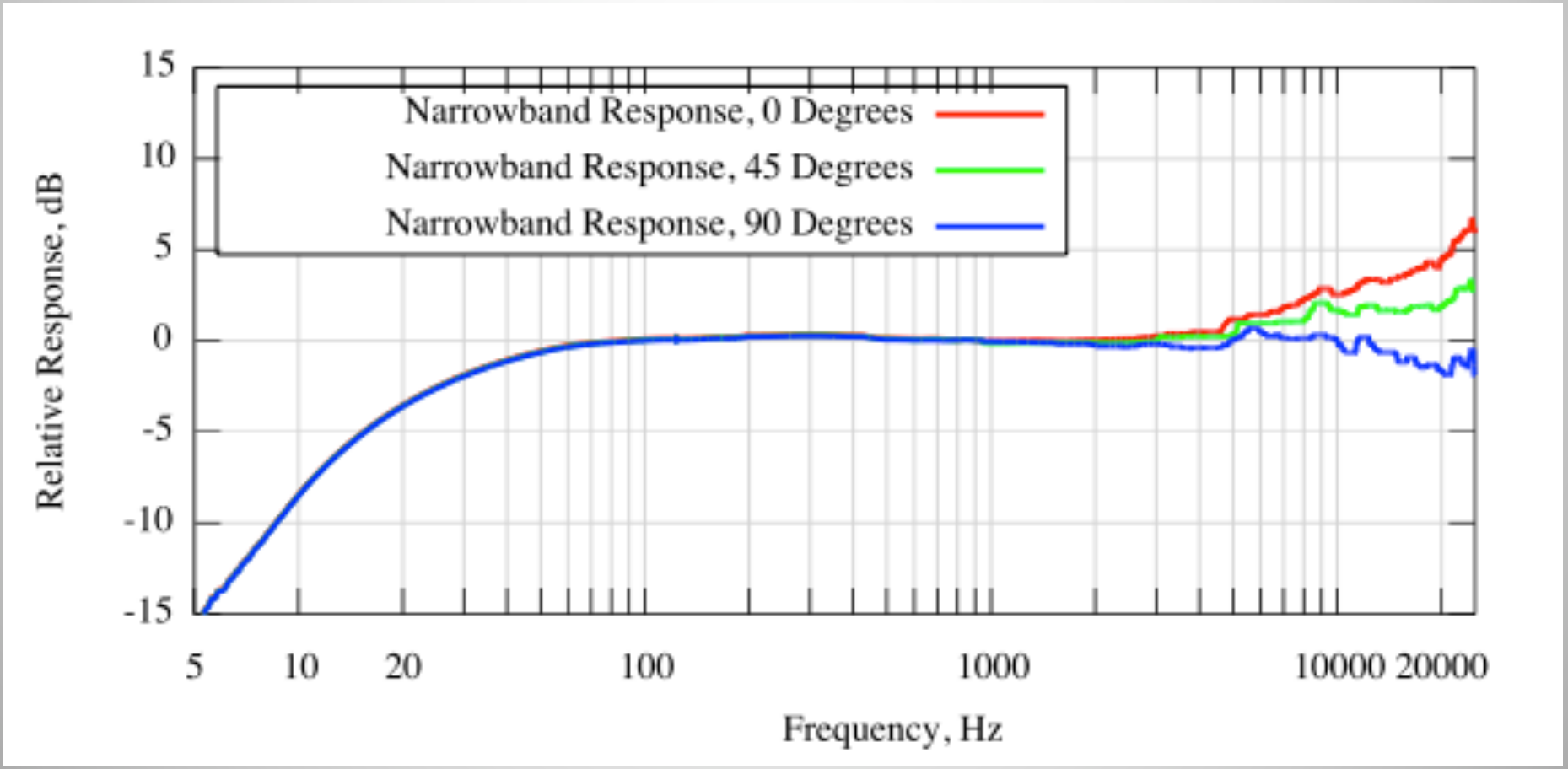
Measurement Microphones

Rational Acoustics RTA-420

(AVLeader PHM919)



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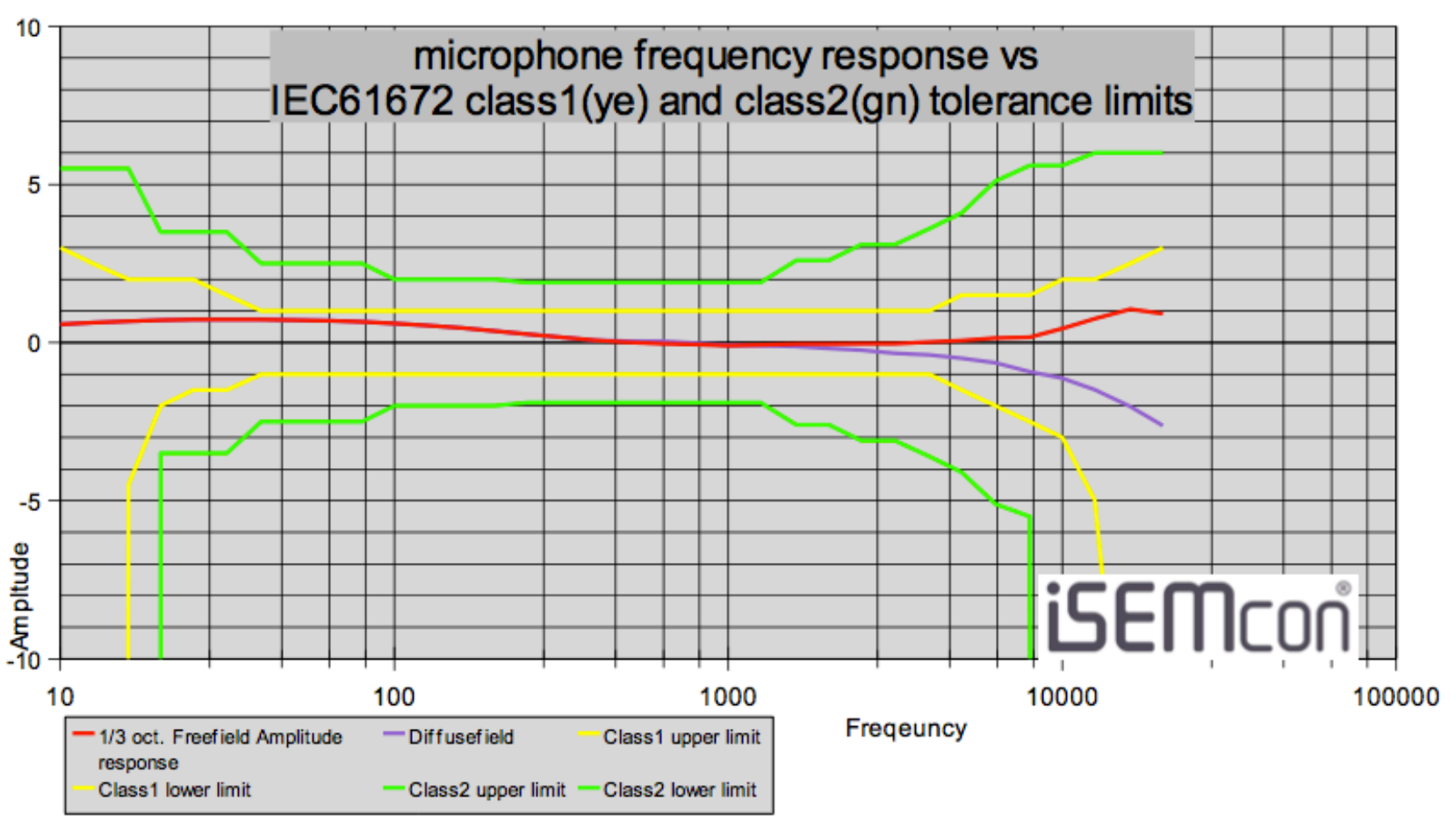
Measurement Microphones

iSEMcon EMX-7150



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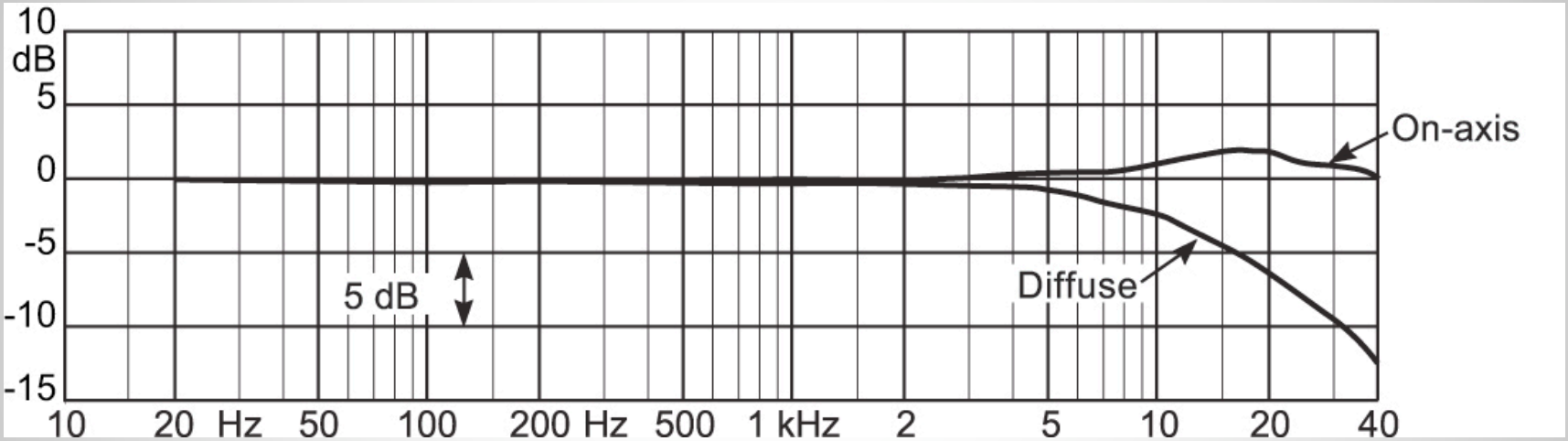
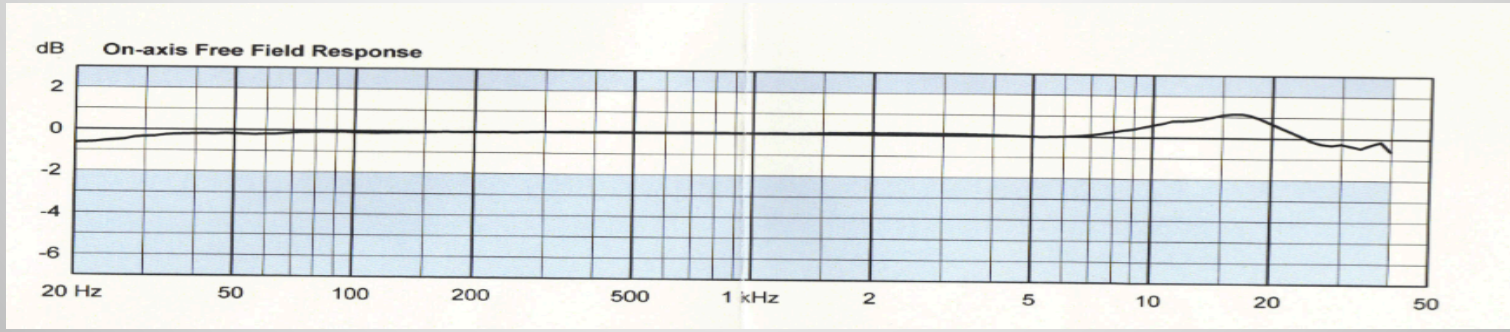
Measurement Microphones

DPA 4007



"Typical"



Measured (S/N 2119248)

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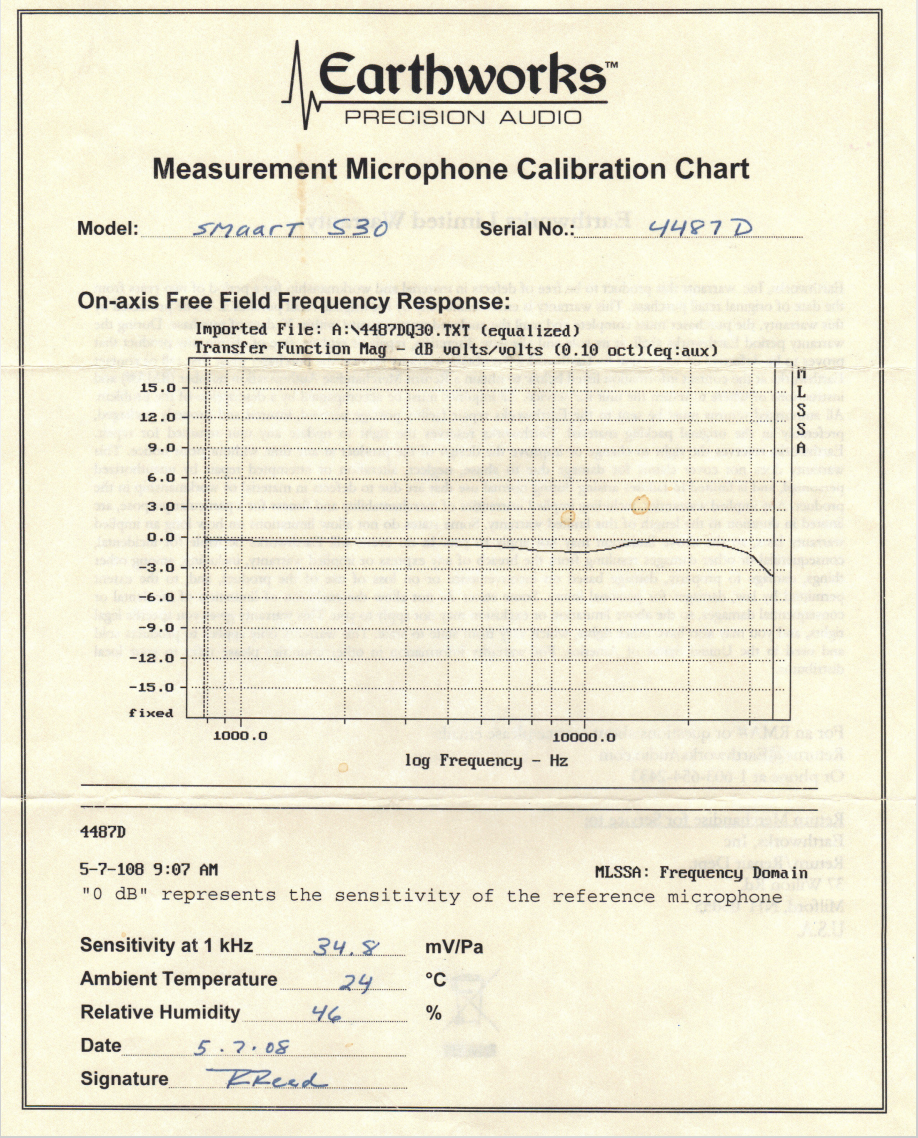
Measurement Microphones



Earthworks™
PRECISION AUDIO

Measurement Microphone Calibration Chart

Model: SMaarT 530 Serial No.: 4487D

On-axis Free Field Frequency Response:

Imported File: A:\4487DQ30.TXT (equalized)
Transfer Function Mag - dB volts/volts (0.10 oct)(eq:aux)

15.0
12.0
9.0
6.0
3.0
0.0
-3.0
-6.0
-9.0
-12.0
-15.0
fixed

1000.0 10000.0

log Frequency - Hz

MLSSA

4487D

5-7-108 9:07 AM MLSSA: Frequency Domain

"0 dB" represents the sensitivity of the reference microphone

Sensitivity at 1 kHz 34.8 mV/Pa
Ambient Temperature 24 °C
Relative Humidity 46 %
Date 5.7.08
Signature RReed

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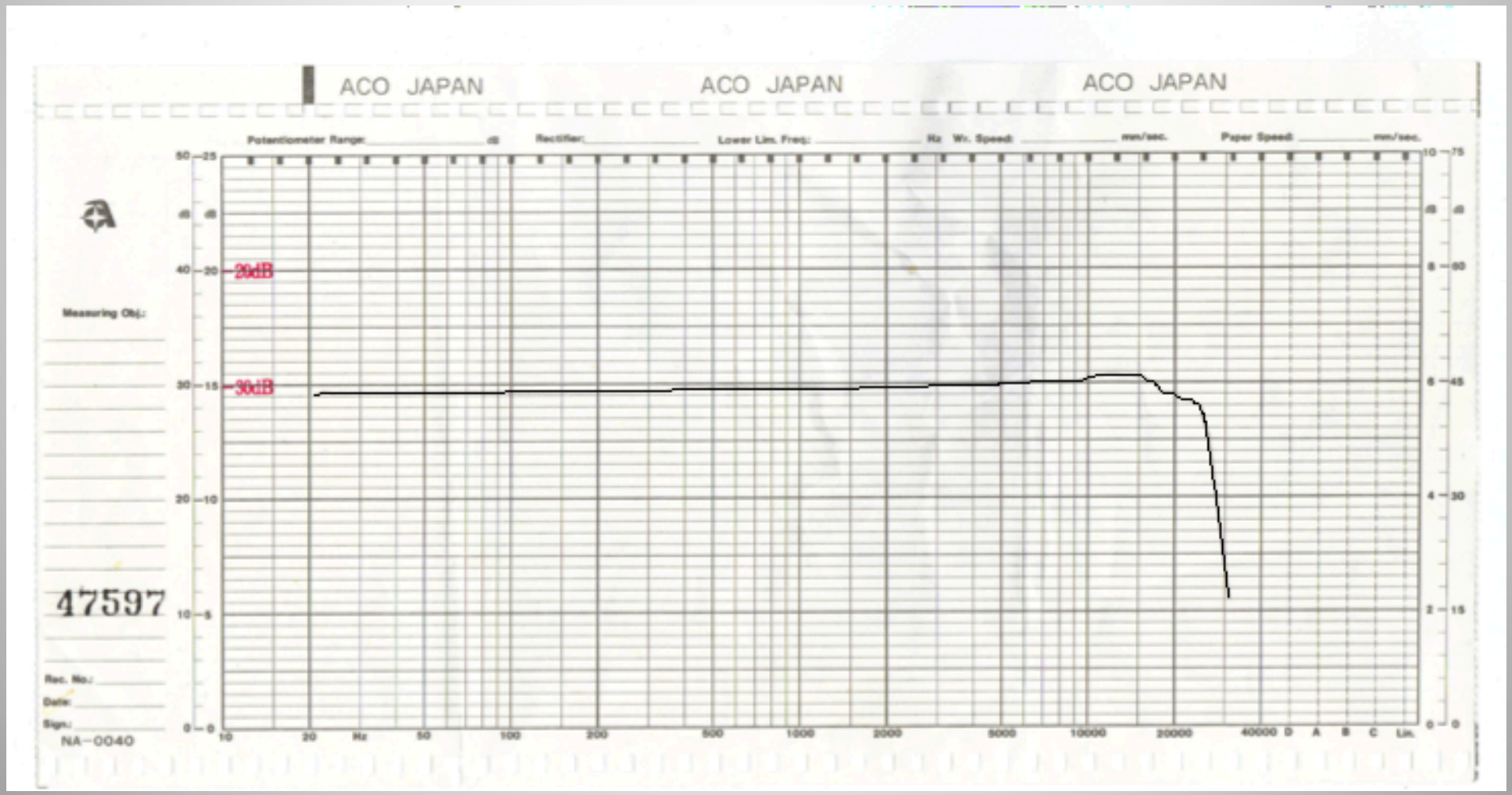
Measurement Microphones

ACO Pacific 7052PH



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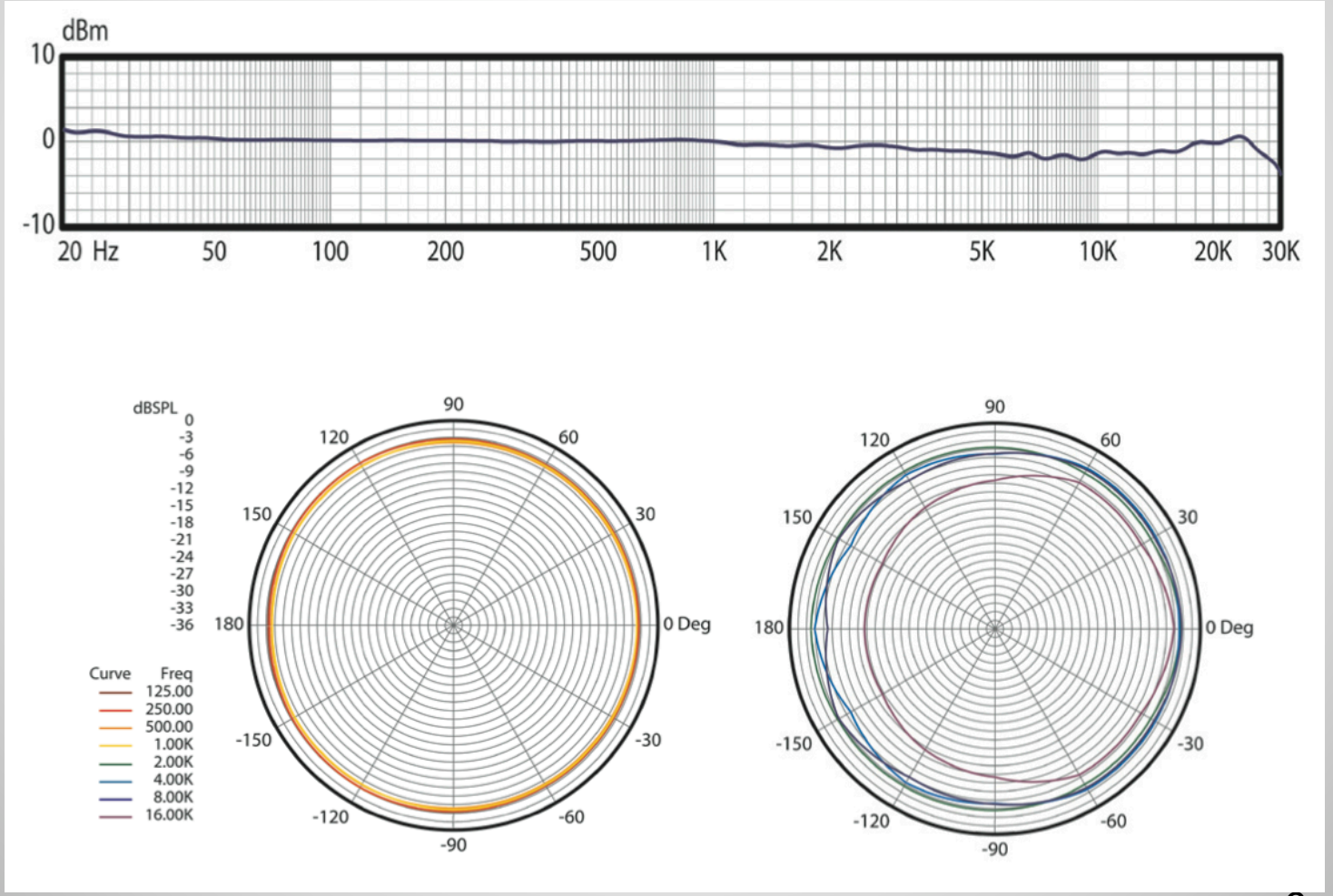
Measurement Microphones

Audix TM1



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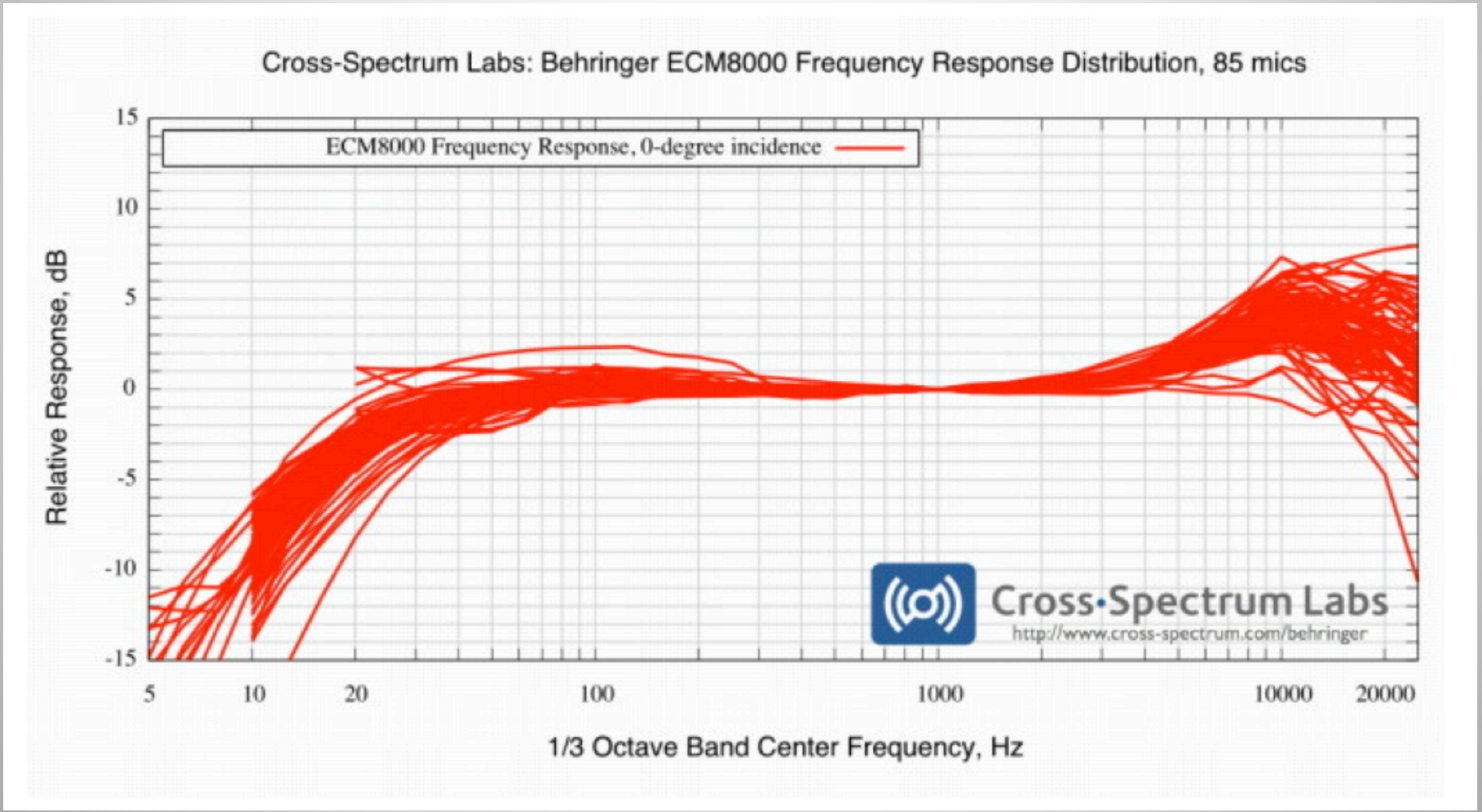
Measurement Microphones



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Measurement Microphones

A Comparison of Published Specifications*

Manufacturer	Model	1%/Max SPL	Dyn. R	Self Noise	Sens	Capsule
DPA	4007	148/155 dBSPL	124 dB	24 dBA	2.5 mV/Pa	12mm (0.5") Metal
ACO Pacific	7052PH	150 dBSPL	130 dB	20 dBA	22 mV/Pa	12mm (0.5") Metal
EarthWorks	S30/M23	136/142 dBSPL	120 dB	22 dBA	30 mV/Pa	7.0mm (0.25") Poly
Audix	TM-1	130/140 dBSPL	112 dB	28 dBA	6.5 mV/Pa	7.7mm (0.25") Poly
iSEMcon	EMX-7150	140/146 dBSPL	115 dB	30 dBA	6 mV/Pa	7.7mm (0.25") Poly
RA (AVLeader)	RTA-420	112/118 dBSPL	90 dB	30 dBA	8 mV/Pa	10mm (0.25" capsule) Poly

* These are "typical" specifications

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Step 2:
Individual Systems

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Our System Alignment Process
Step 2:

- **Verify all individual speaker systems (arrays) + initial EQ**

For each system:

1) Verify system coverage. Determine limits of coverage area. Adjust speaker aim and placement if possible / necessary.

2) Evaluate consistency of coverage
   a) Level
   b) Frequency Response

3) Measure system to determine typical frequency response in listening area.

4) Adjust frequency response (primarily thru array level EQ)
   a) Address consistent response issues (loading, HF airloss, etc)
   b) Avoid high-Q adjustments (particularly during first passes)
   c) Keep LF perspective (what will happen when: speakers add, people arrive?)
   d) Listen before getting tweaky

20% / 80%

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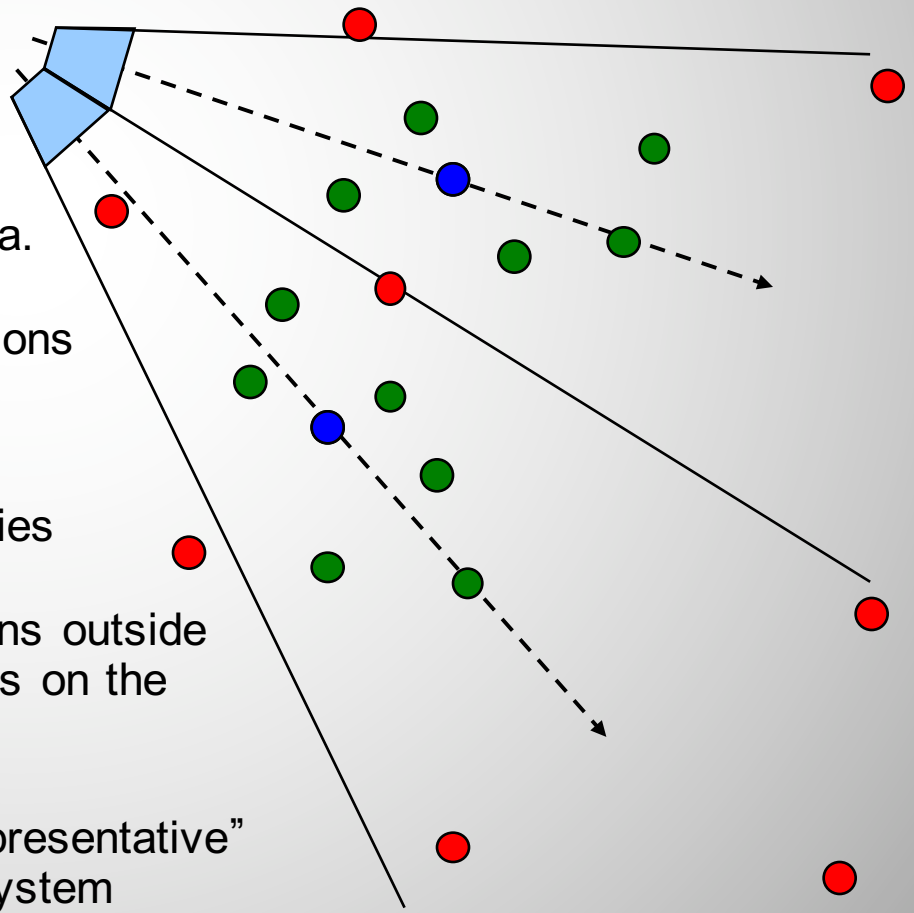
Measuring Average (Typical) Frequency Response . . .

For a given loudspeaker or array



Our goal is to determine the "average" frequency response in its coverage area.

- For this we require measurement positions that will indicate the "typical" frequency response of that system.
  - a) Avoid position-dependent anomalies
  - b) Avoid using measurement locations outside the core coverage area – locations on the edges of coverage
  - c) If possible, determine a good "representative" measurement location for each system

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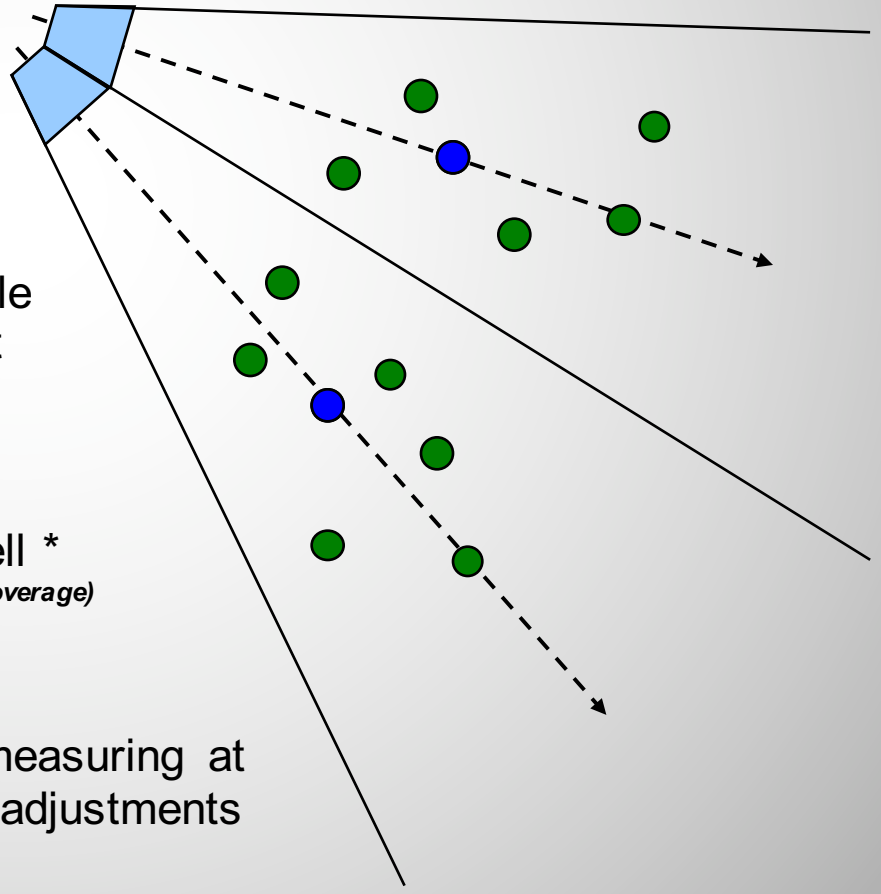
Measuring Average (Typical) Frequency Response . . .

Obtaining our average:

Just as we average consecutive TF measurements at a single position to exclude noise and other temporal deviations / anomalies, we average together TF measurements from multiple positions to exclude position-dependent anomalies.



Q: How many measurement positions?

A: In practice, 3 or 4 works well *

* *(Assuming consistent coverage)*

Q: Why the "representative" position?

A: To reduce the need for re-measuring at multiple position after making adjustments

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Measuring Something that Doesn't Exist

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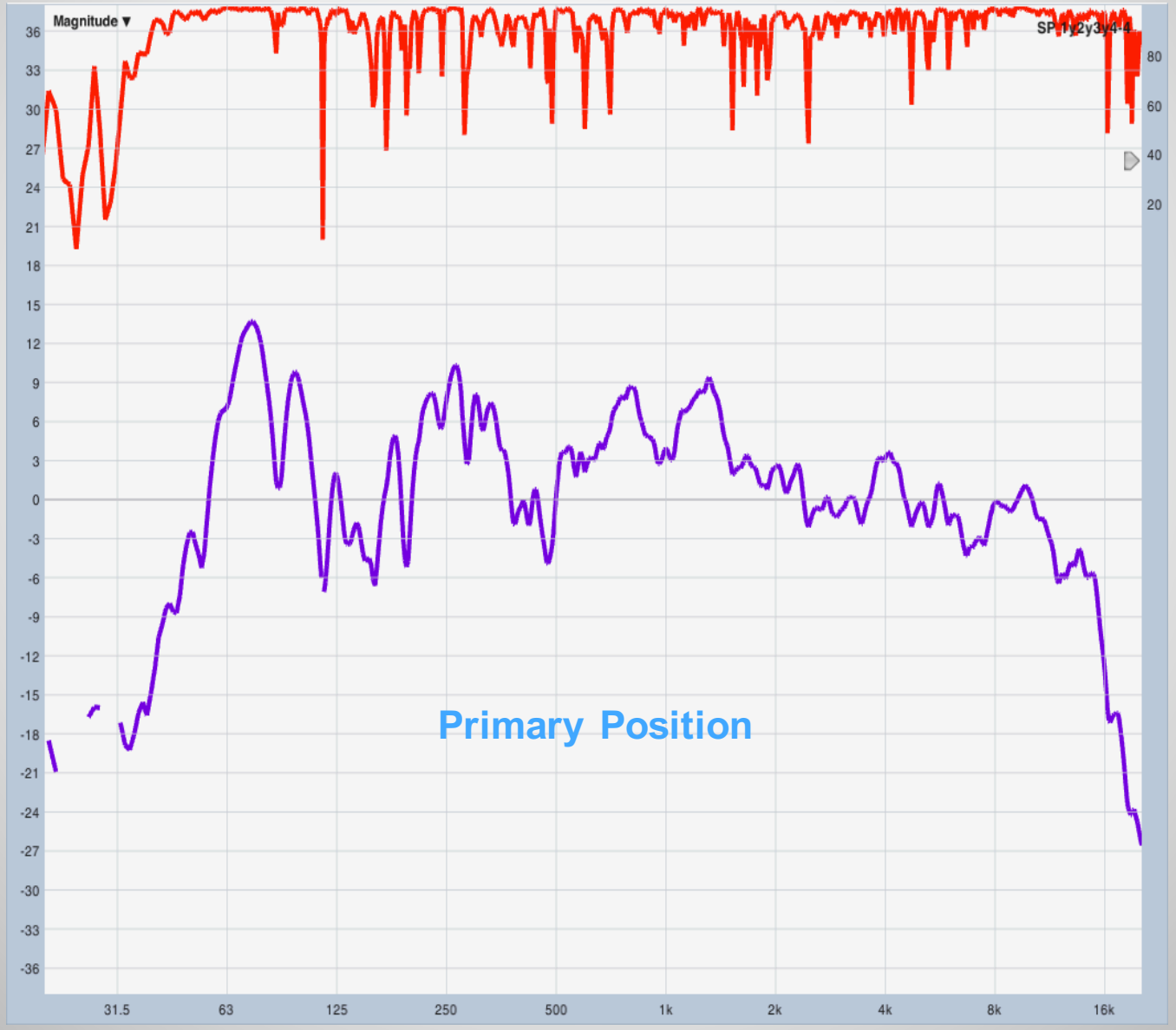
Our primary position



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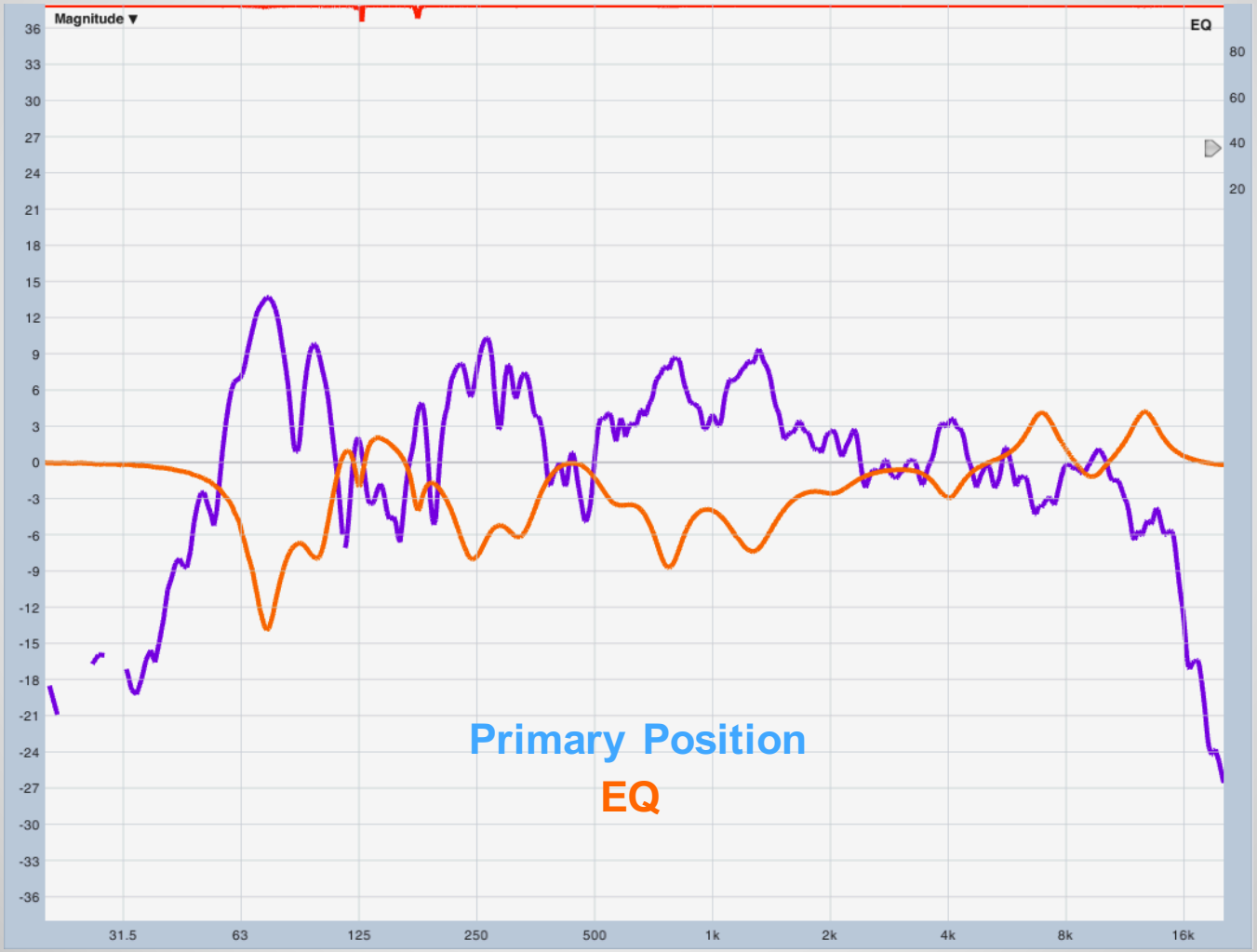
I got tons ‘o philters



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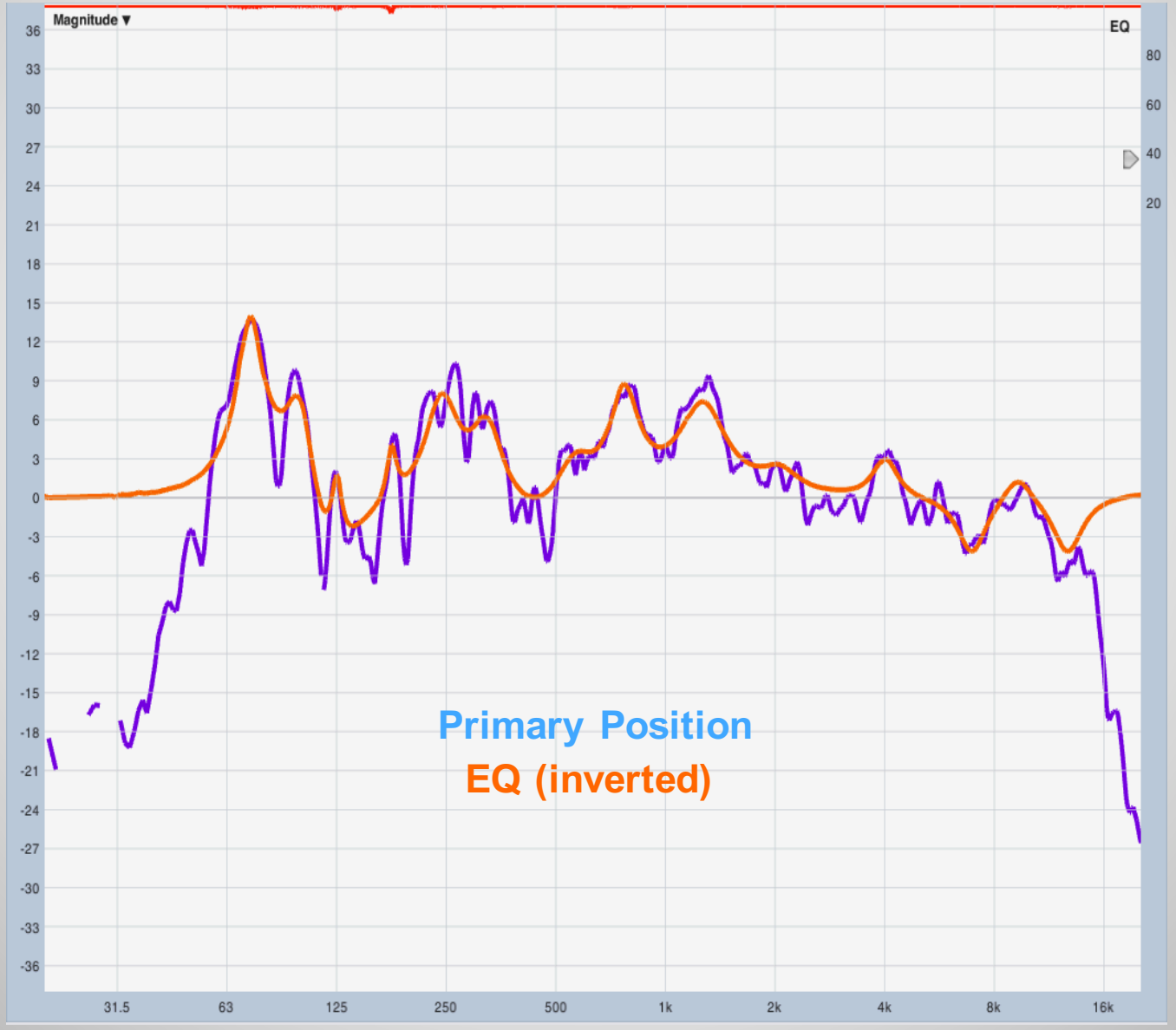
Invert EQ and Match it – So Easy!



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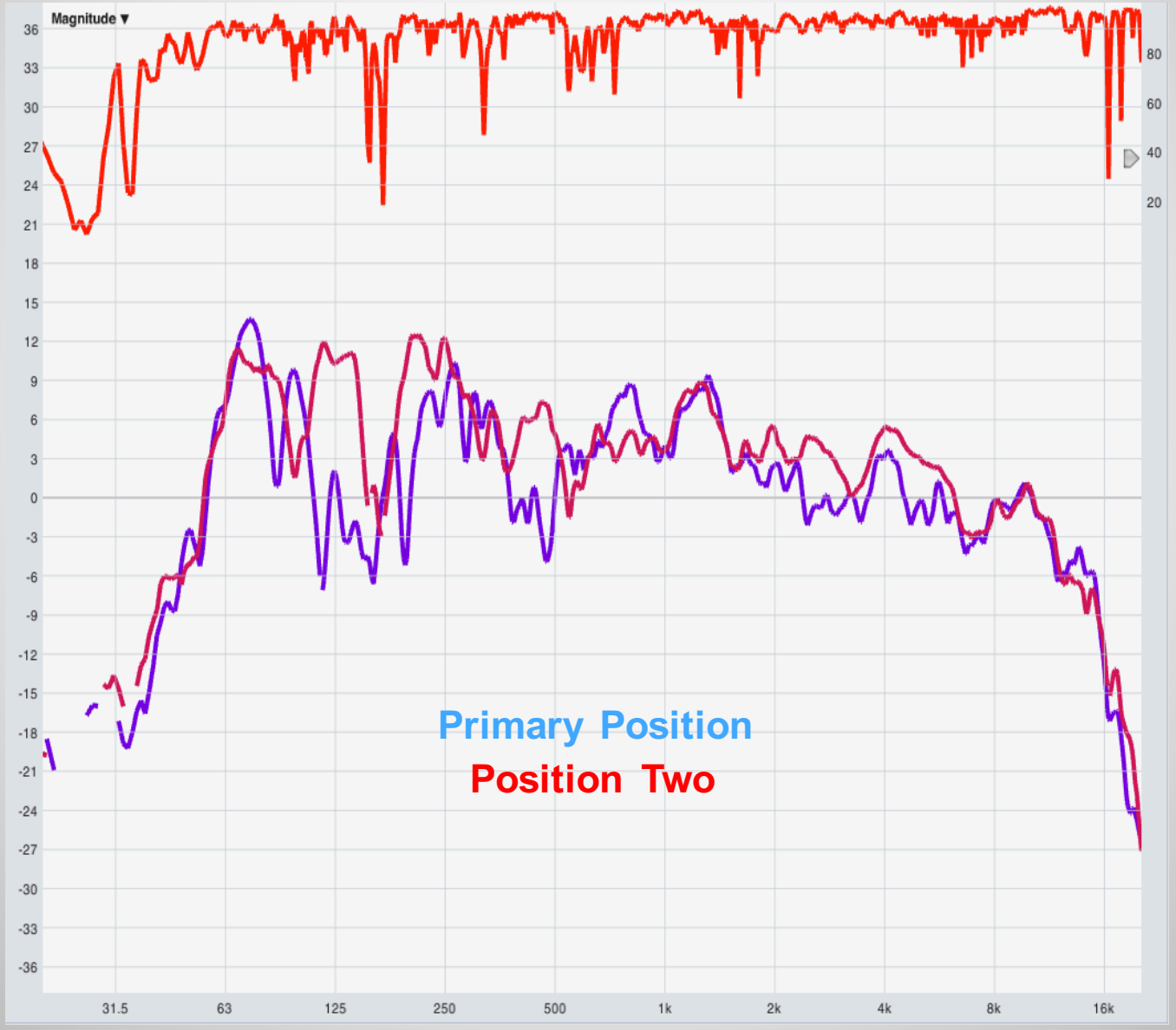
Uh, there are other seats



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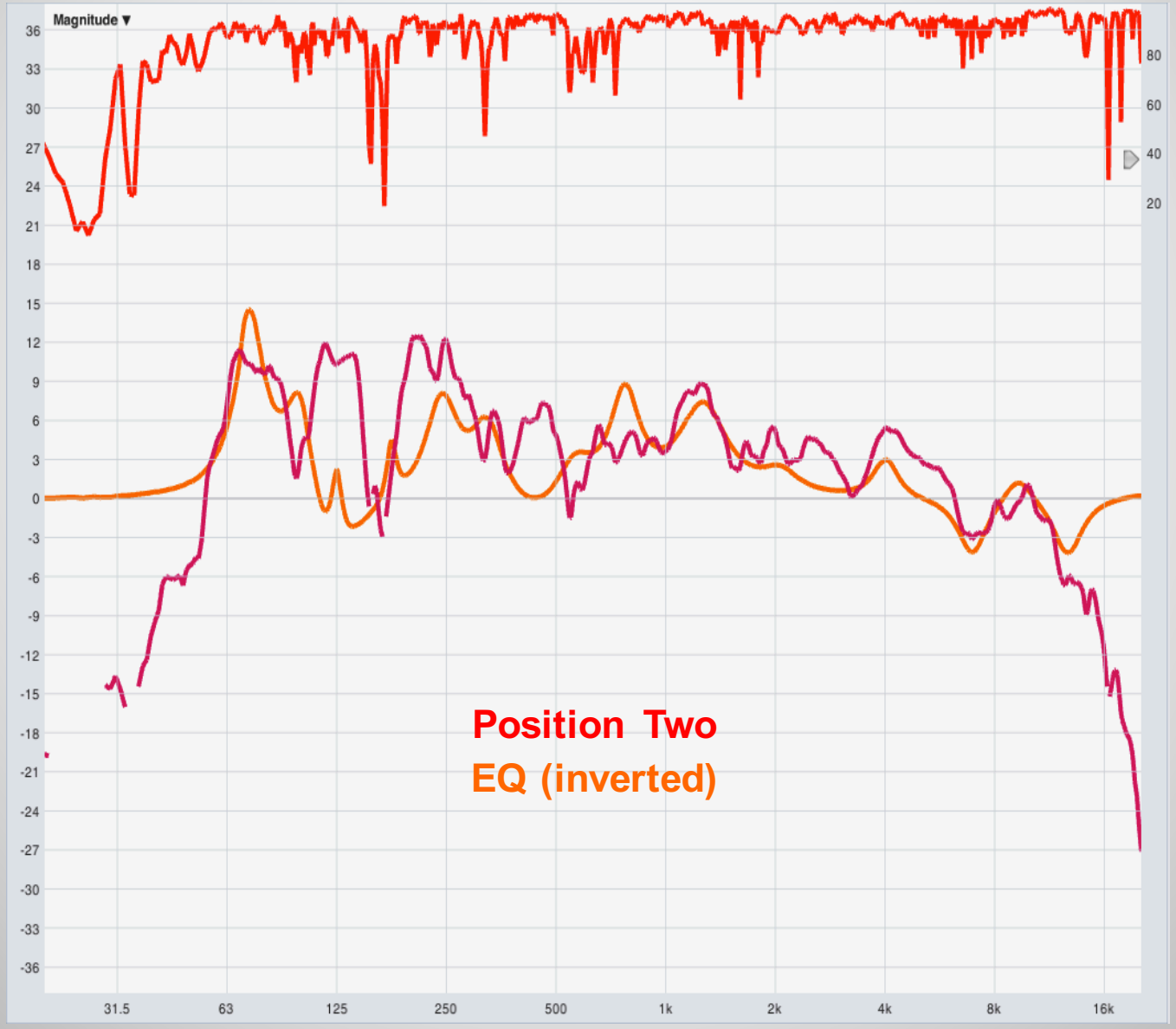
Still complementary?



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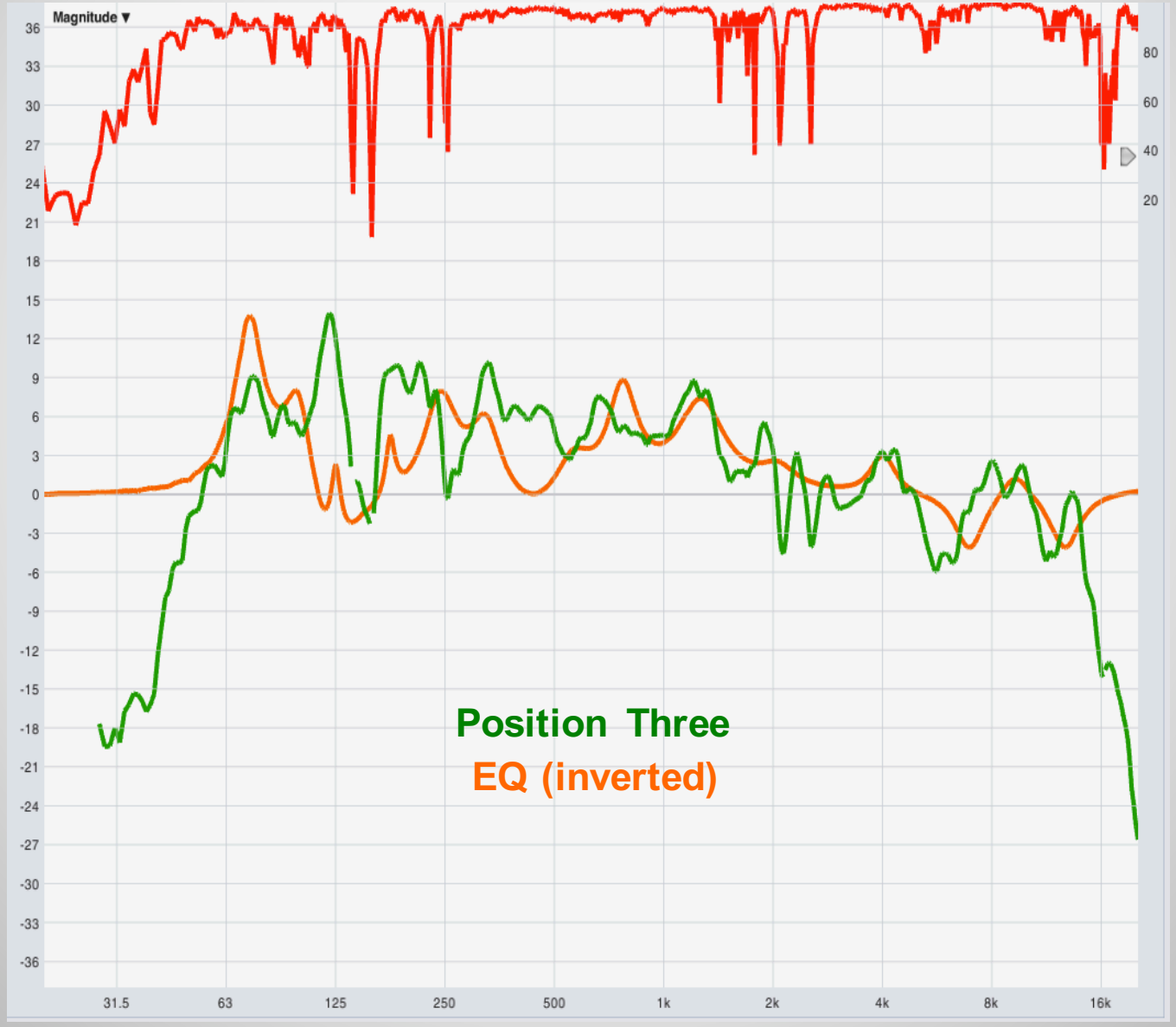
Uh, erm . . .



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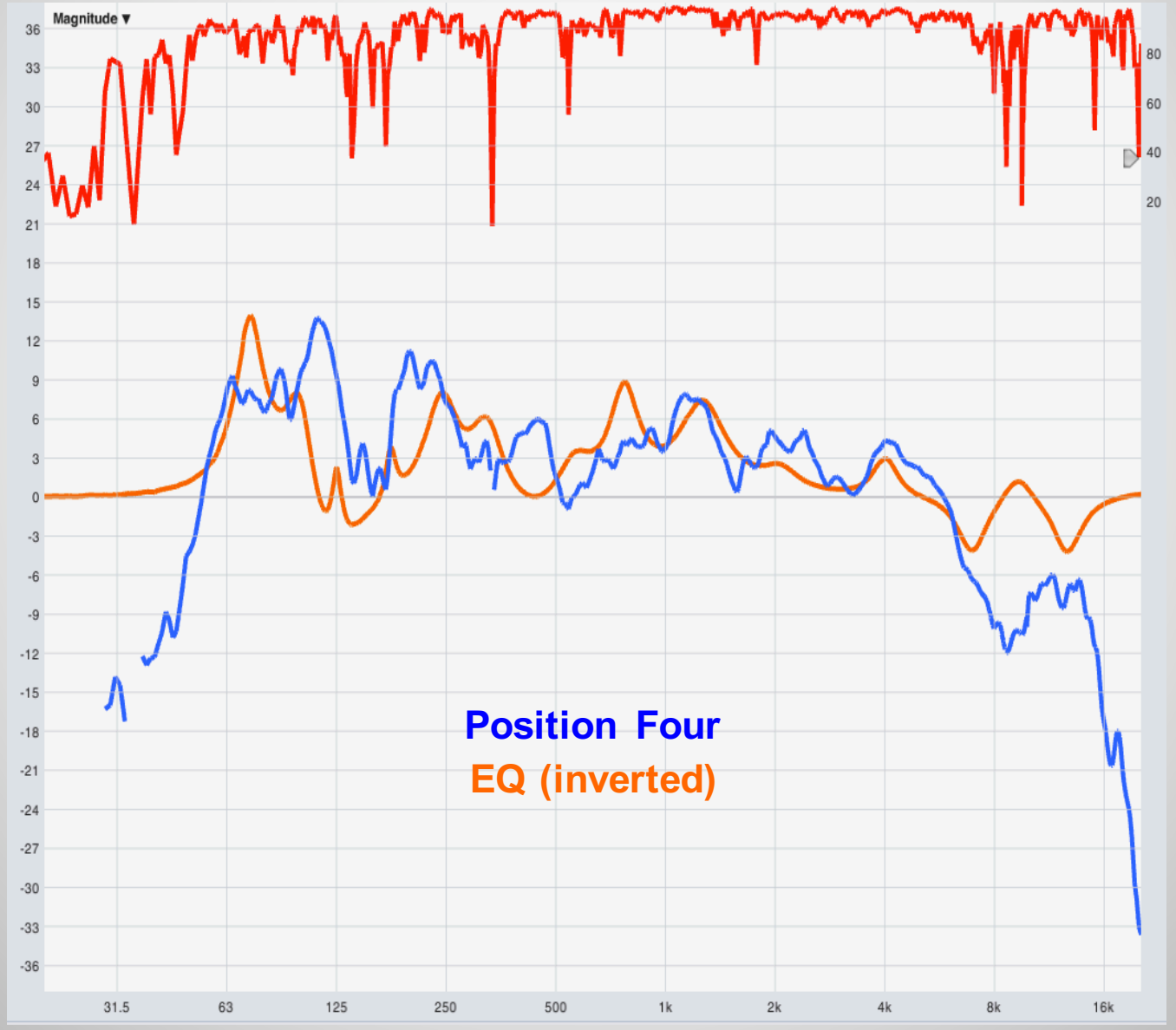
Hmm



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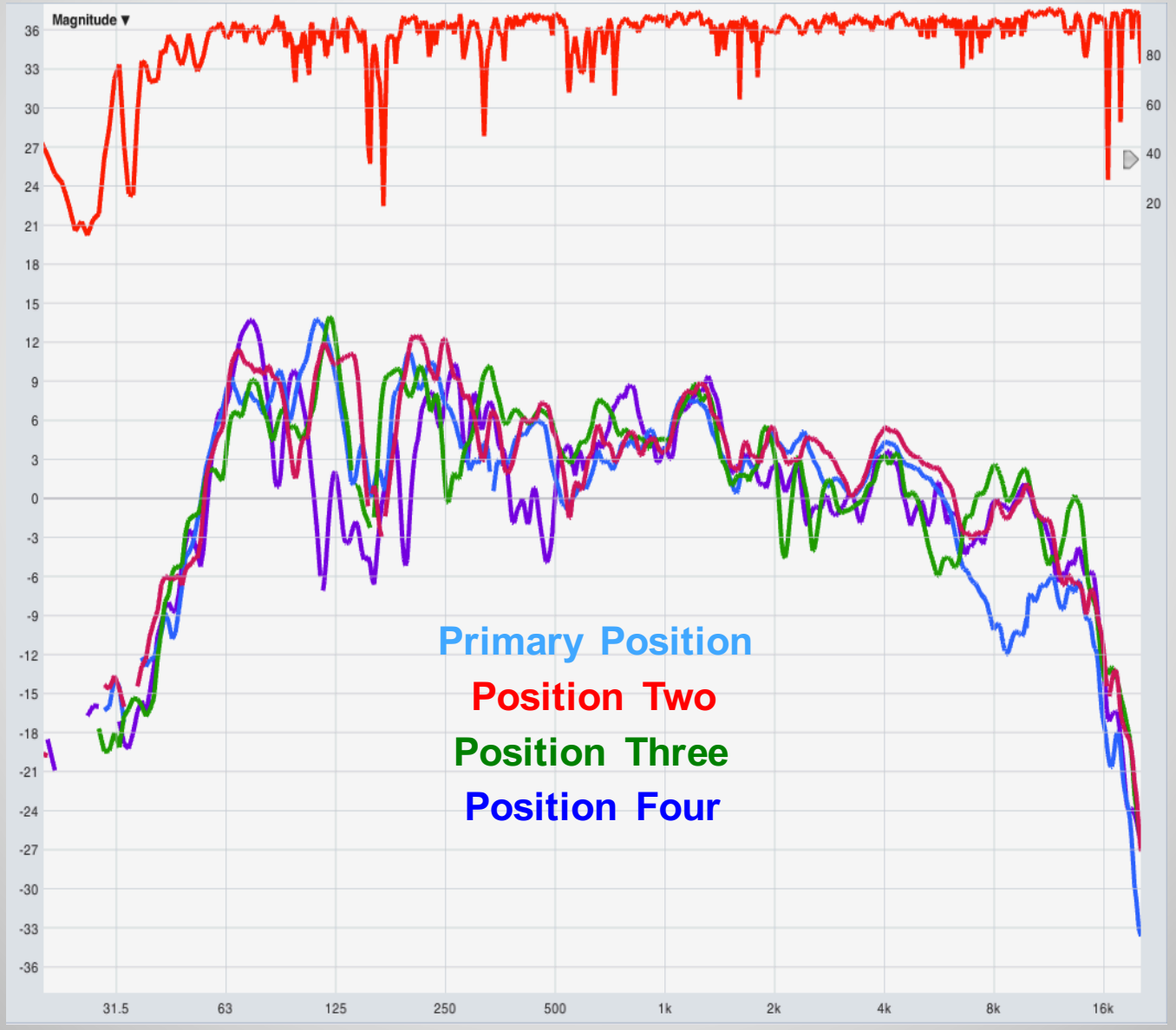
Be a forester not an arborist



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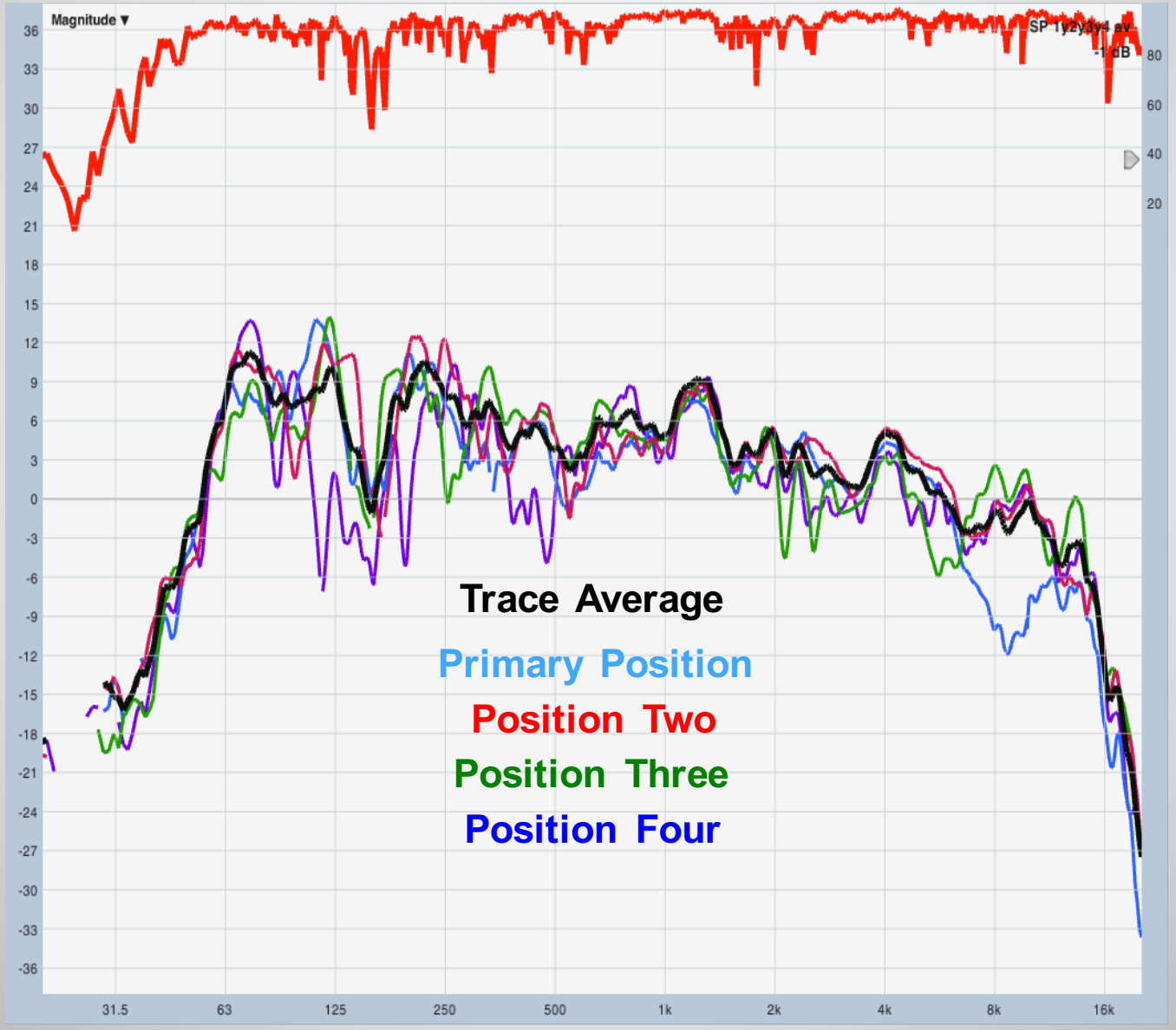
Average data can help to show trend



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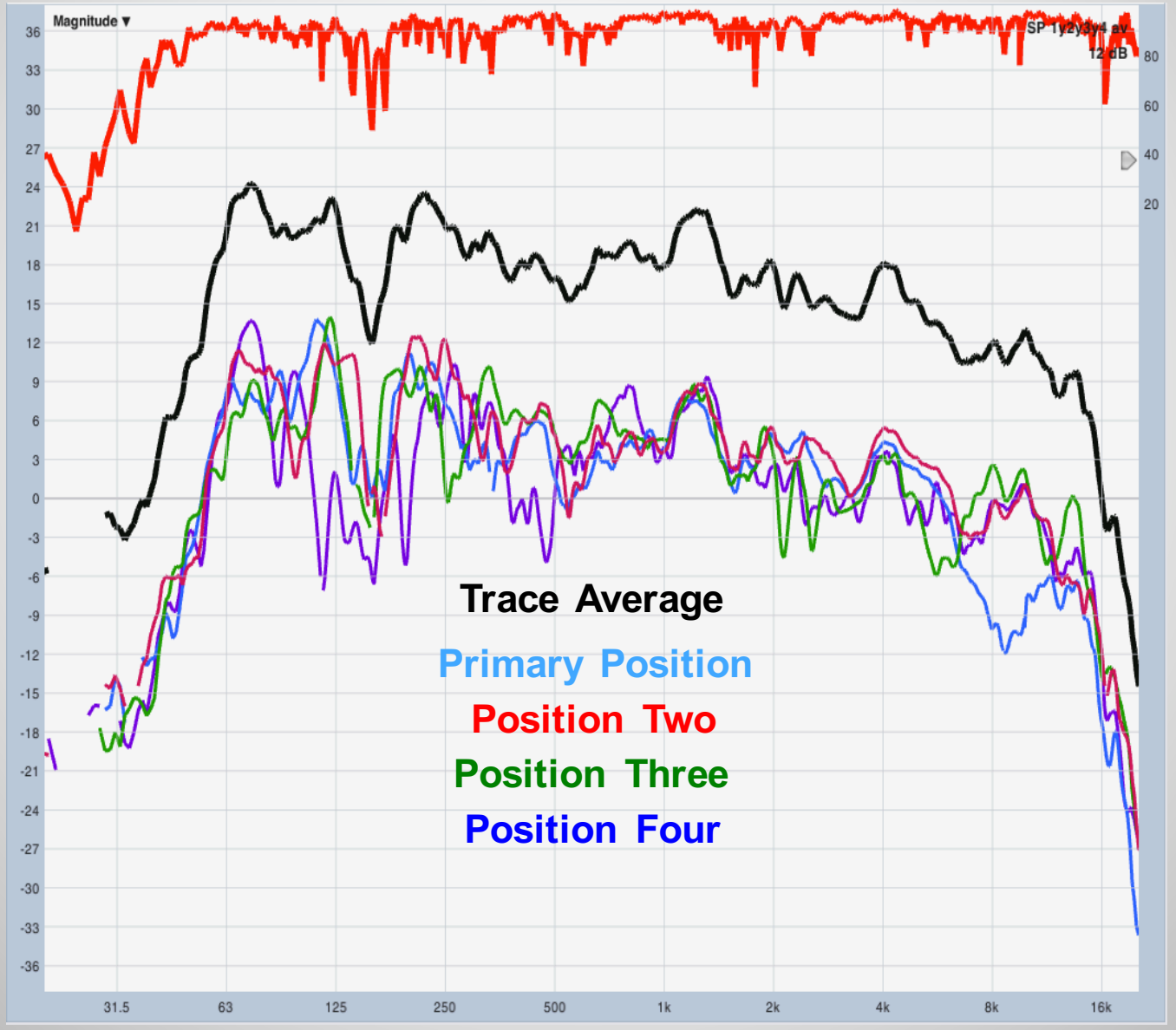
Envelope?



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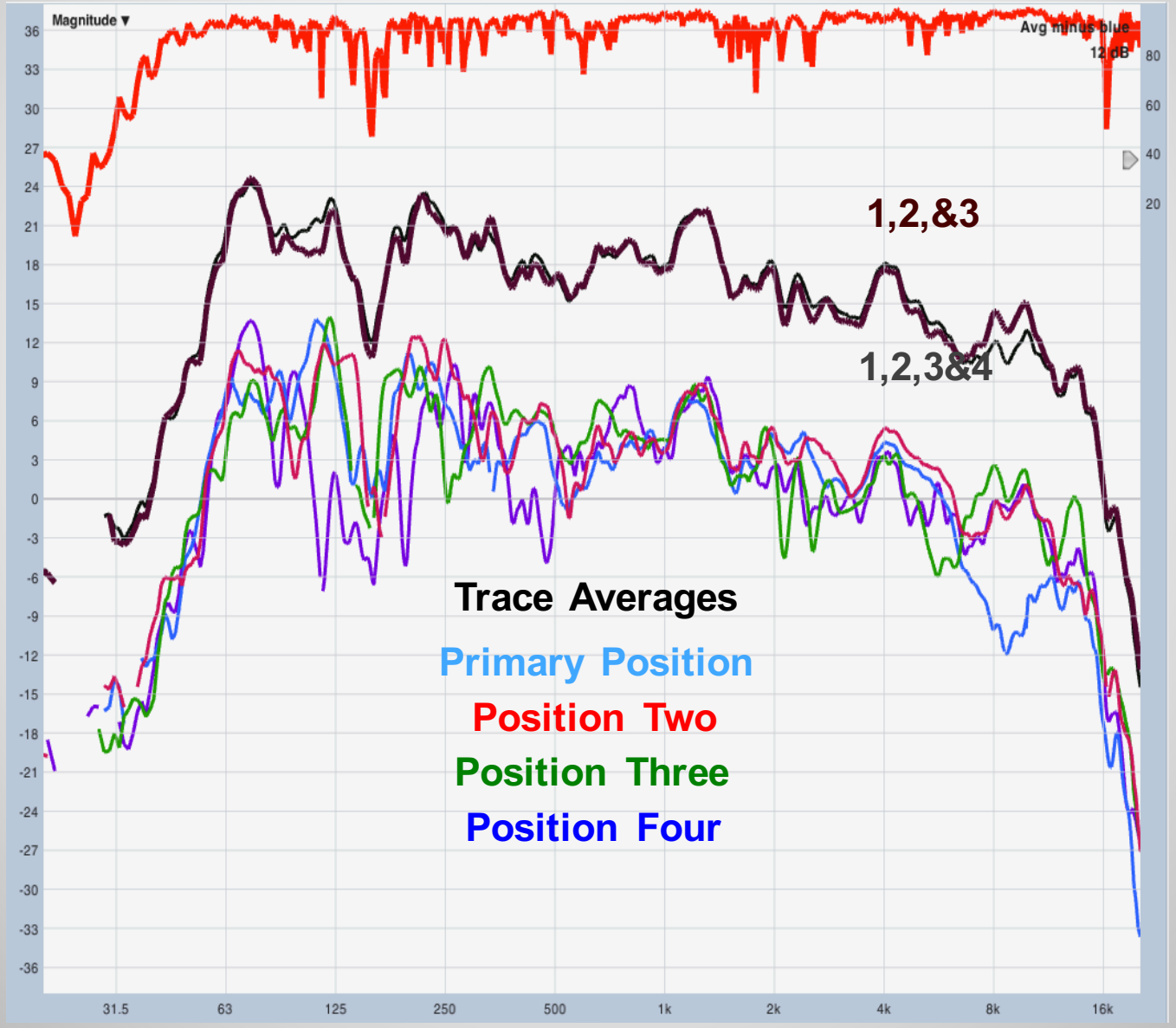
What is the Impact of One Trace? HF – Another Ave without Blue



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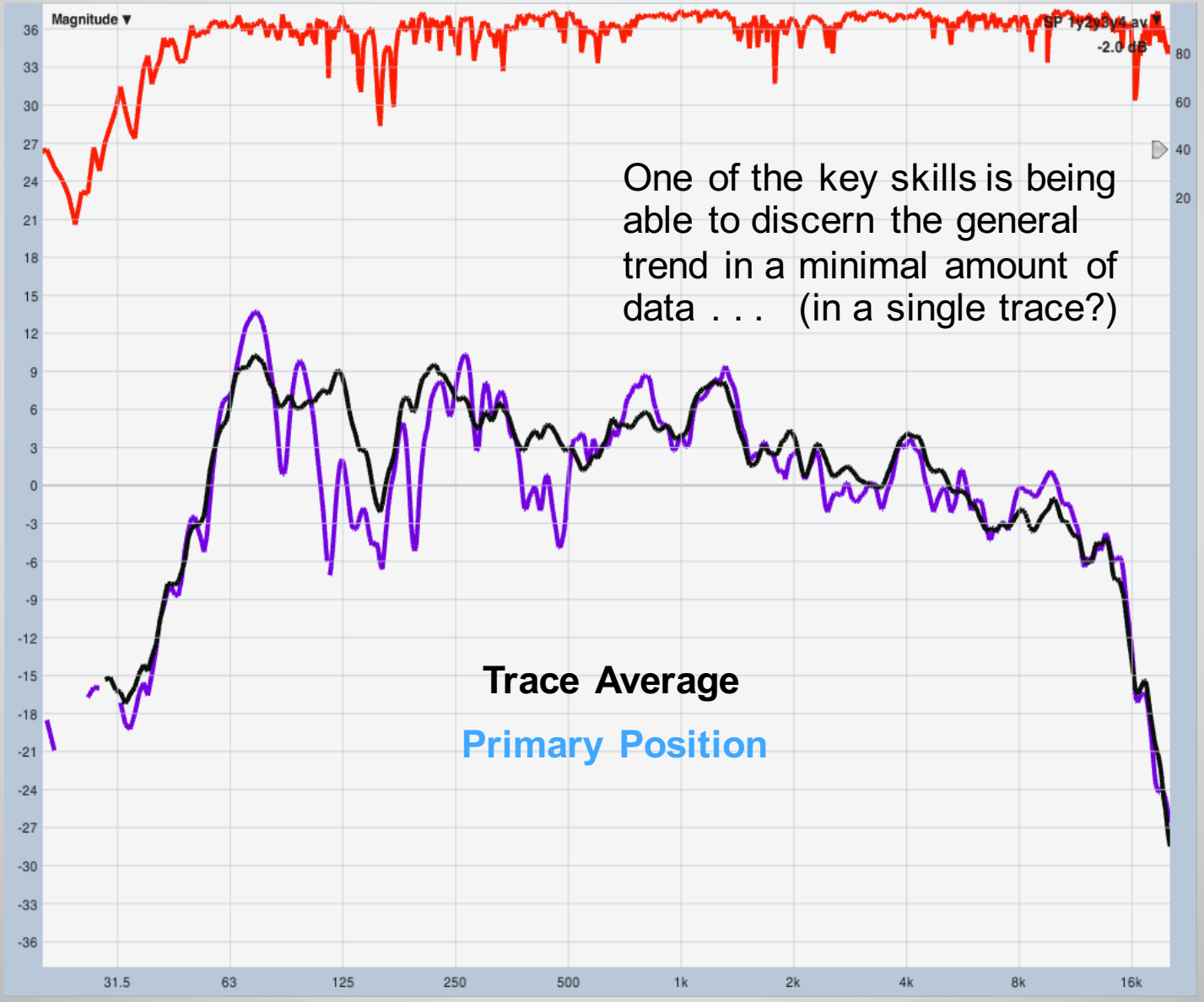
Can you see the trend?



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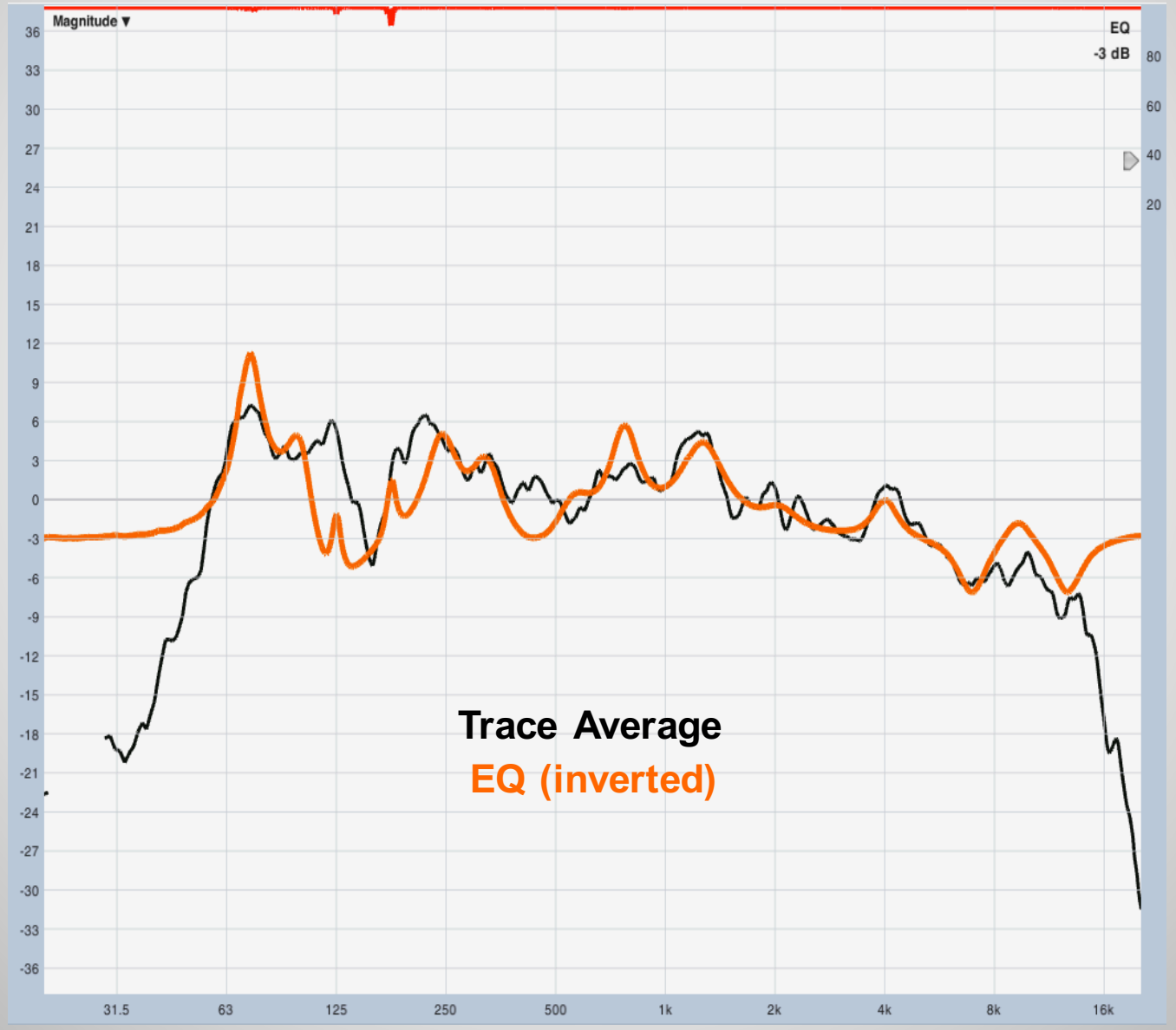
Maybe we've gone too far



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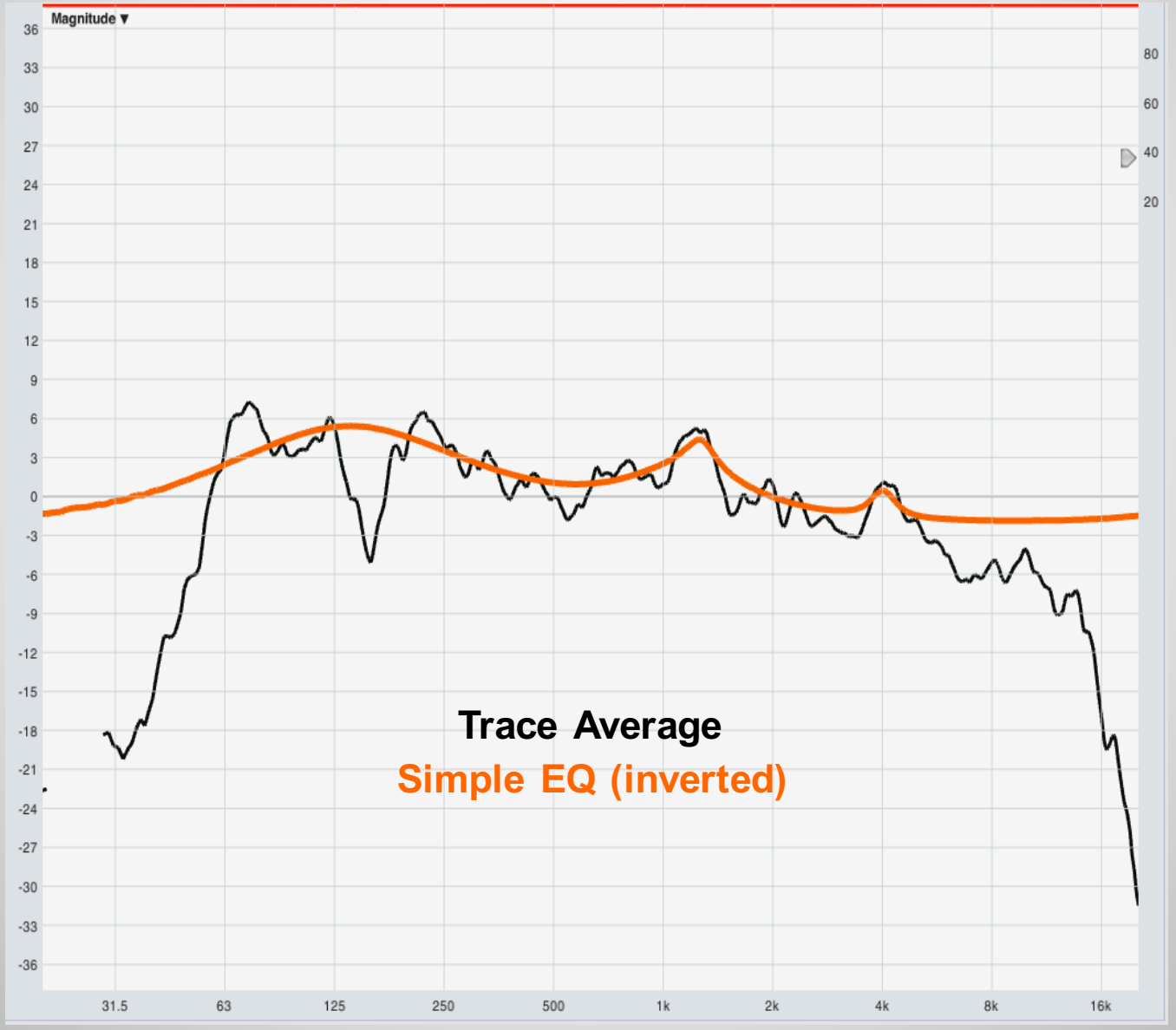
Simplicity



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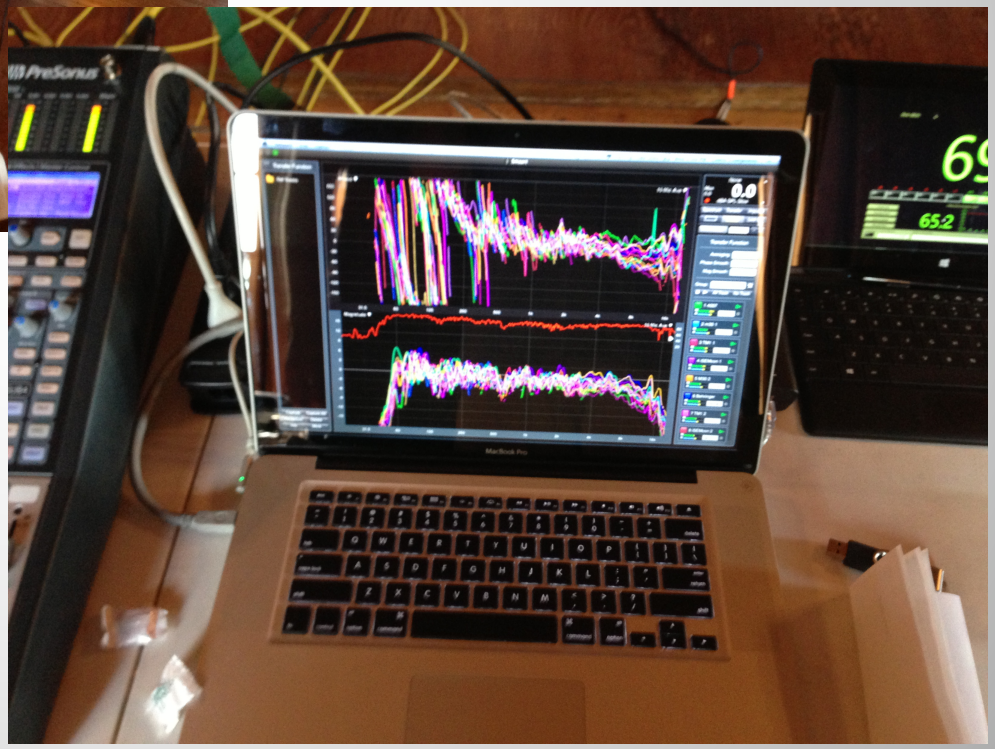

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