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OPTIMAL TRANSMIT VOLUME CONDITIONS FOR MISSION CRITICAL VOICE QUALITY OF EXPERIENCE MEASUREMENT SYSTEMS

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INTRODUCTION

- MCV QoE measurement system
  - Push-to-talk communications systems
  - Variety of measurements
- Measurements require consistency, comparability, repeatability
- Accurately deliver high quality measurement systems
  - Fellow researchers, industry, first responders
- Ensure due diligence on isolating contributors of variance
- One such contributor: system volume settings

VOLUME

- Receiver volume
  - Receiving user's device settings
  - Impacts how well they would hear a message
  - If too high, receive device in measurement system overdriven
- Transmit volume
  - Transmitting user's loudness
  - Too quiet or loud: radio will try to compensate
    - Mixed results, could impact audio
  - Problems may propagate as the signal travels through the communications system
- Consistent input into devices for testing
  - Devices behave the same way
  - Not putting certain devices, technologies at a disadvantage

OVERVIEW

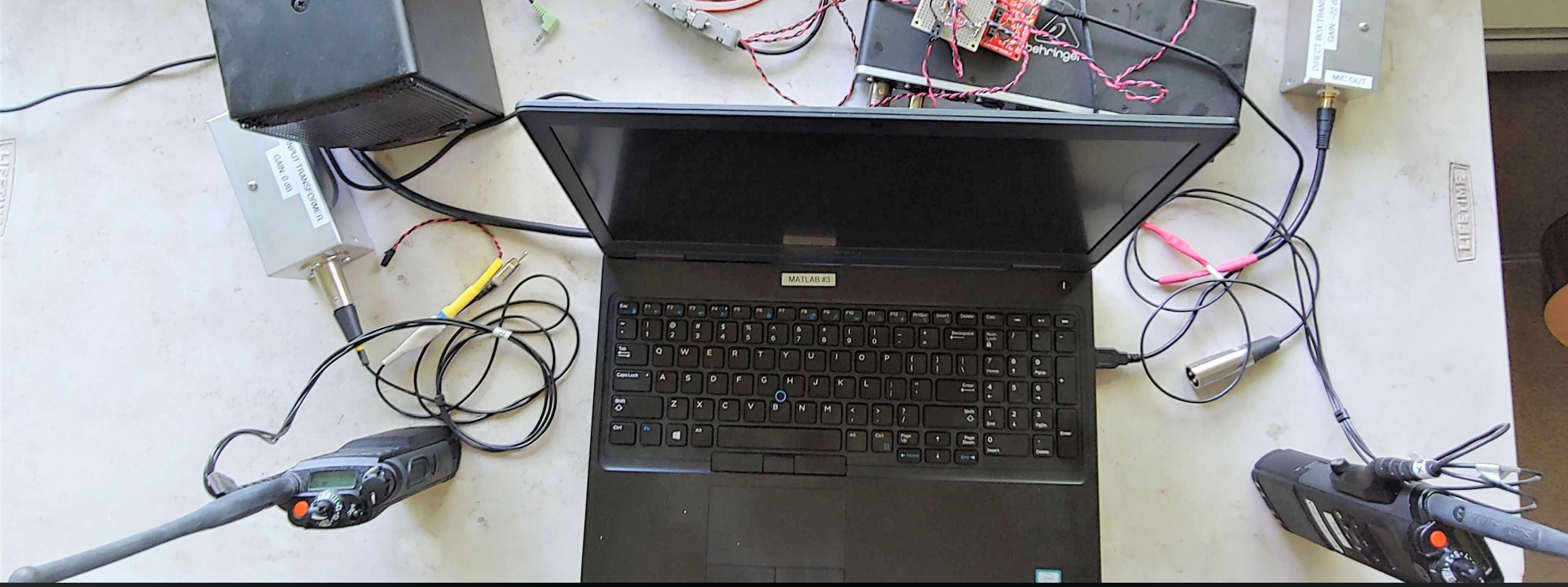
- Goal
  - Measurement that captures audio distortion levels across a series of transmit volume settings
  - Present system users with optimal settings
- Presentation Focus
  - Development of the distortion detection
  - Methods developed to find optimal settings

MOTIVATION

- Determine optimal volume settings before any other MCV measurement
  - First introduced in Mouth-to-Ear Latency
- Previously relied on audio quality measurement tools
- Shift to making the volume settings based on distortion levels
  - Focus on distortion from overdriving speech into a transmit device and how that propagates through the communications system
- Optimal settings have minimal distortion levels
- Internally developed, free to distribute

ACRONYMS

- dBA - values are used to denote speech power after audio is passed through an A-weighting filter
- FSF - Frequency Slope Fit
- PESQ - audio quality measurement



MEASUREMENT SYSTEM

Mouth-to-Ear Latency:
https://doi.org/10.6028/NIST.IR.8206

End-to-End Access Time:
https://doi.org/10.6028/NIST.IR.8275
https://doi.org/10.6028/NIST.IR.8328

OUR TEAM

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OPTIMAL VOLUME TEST OVERVIEW

MEASUREMENT OVERVIEW

Step Number One

01

Prepare MCV measurement system, enter input

Step Number Two

02

Run Volume Adjust test

Step Number Three

03

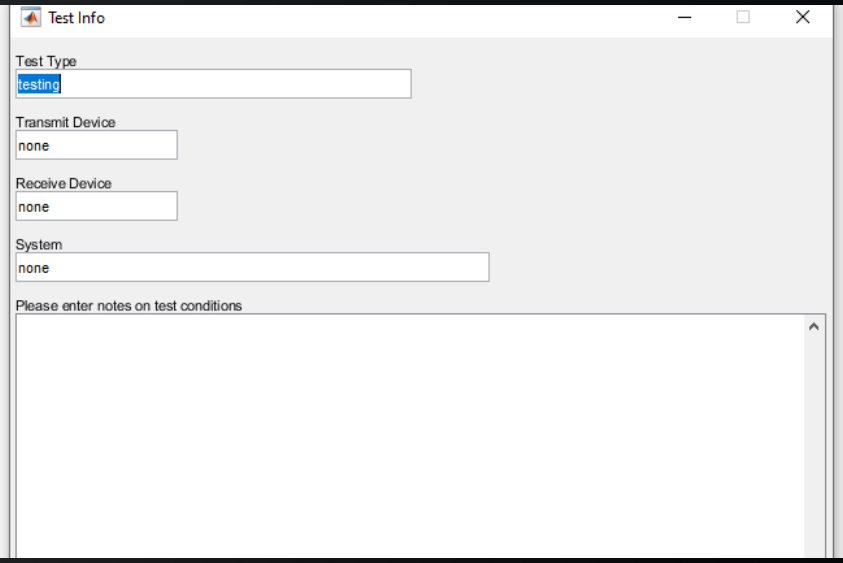
Obtain optimal transmit volume settings

Step Number Four

04

Run all other MCV tests with that combination using optimal settings

MEASUREMENT STEPS – CLOSER LOOK

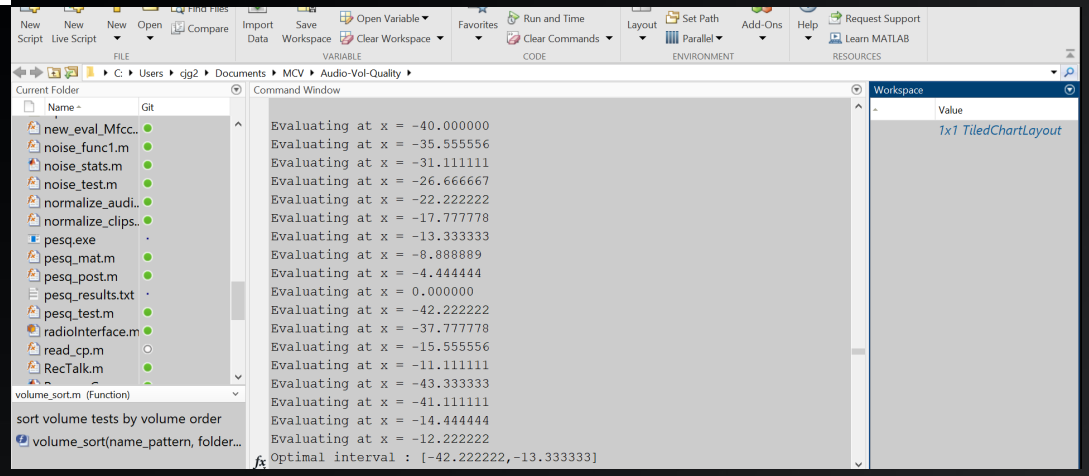


Input Parameters

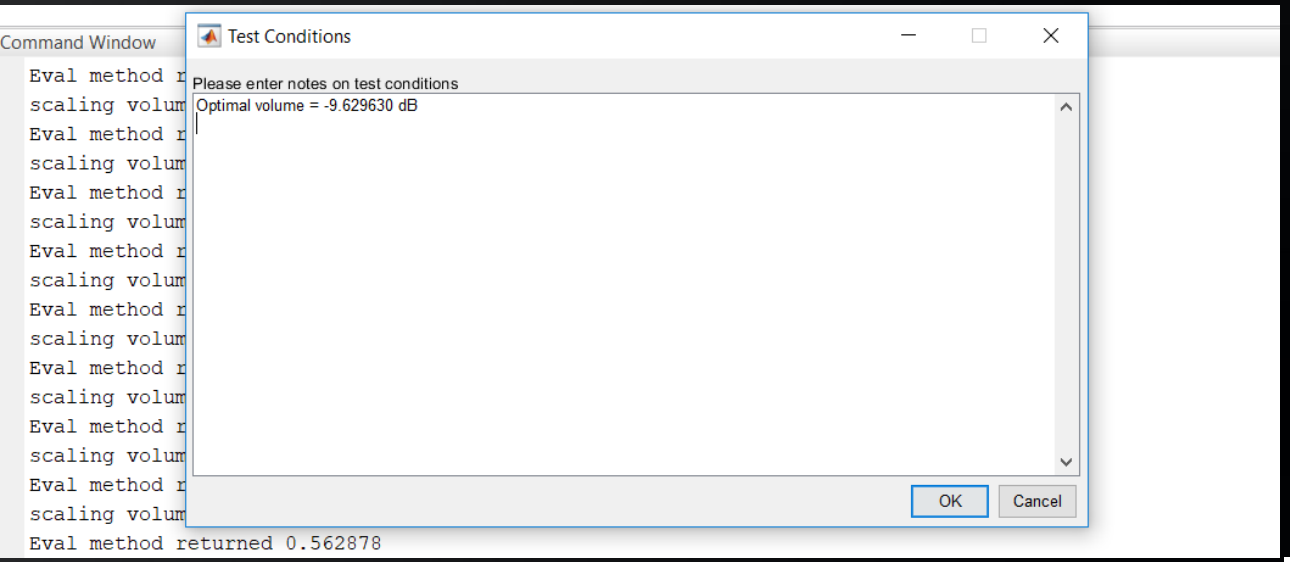
Enter device info, notes, etc.

Volume Adjust Process

Once running, the script automatically runs through various settings until an optimal interval is selected



MEASUREMENT STEPS - OUTPUT

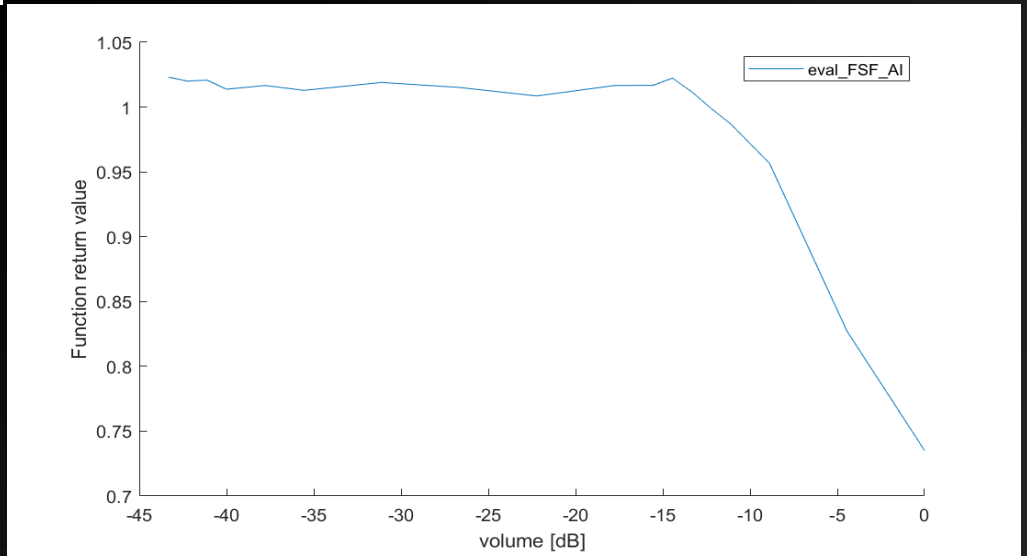


Obtain Optimal Settings

System end notes automatically include the optimal transmit volume setting

Output Plot

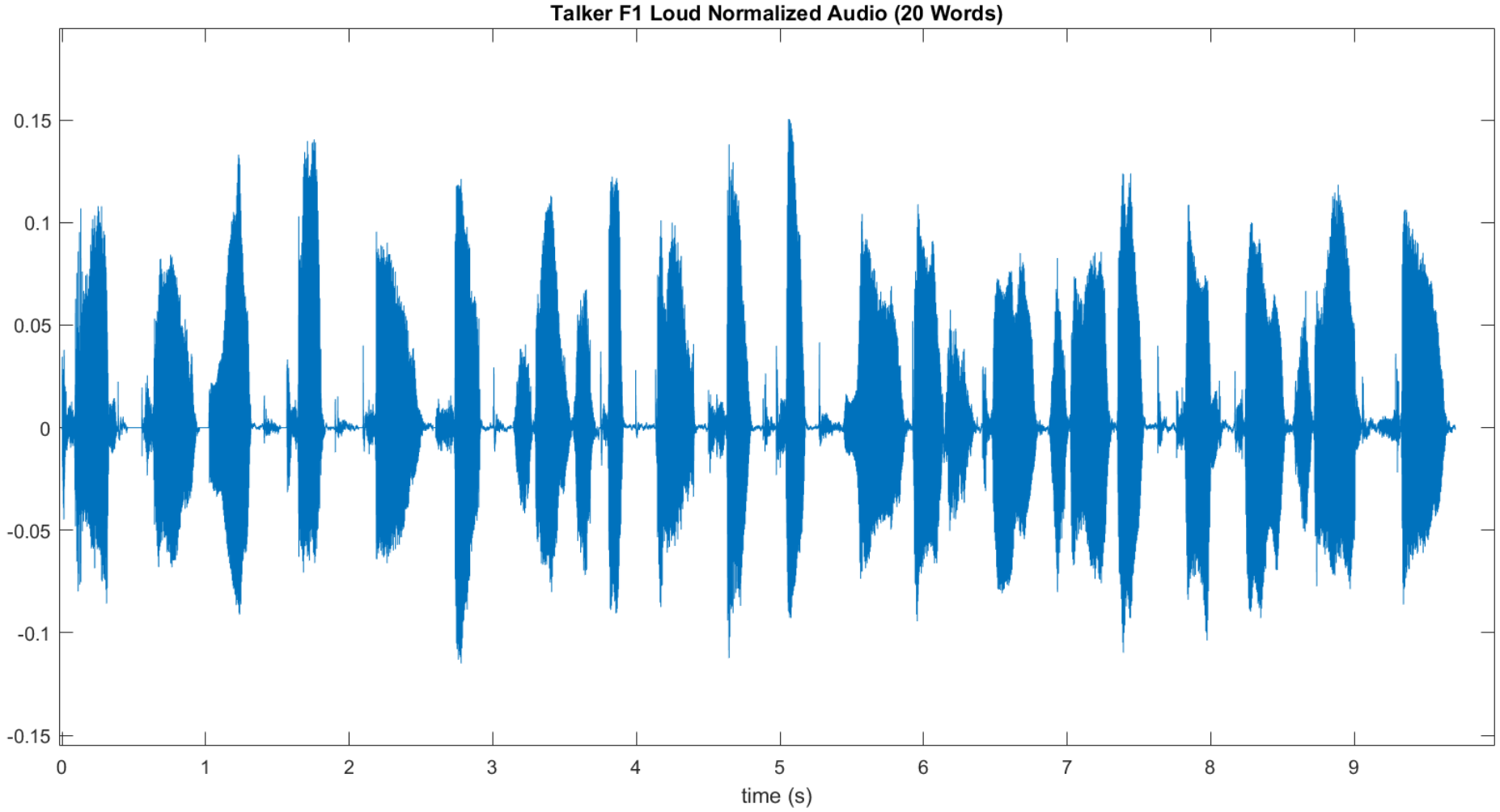
The output shows the full range of settings checked and the average of the scores at those settings



MEASUREMENT DESIGN

DEVELOPING AUDIO FILES

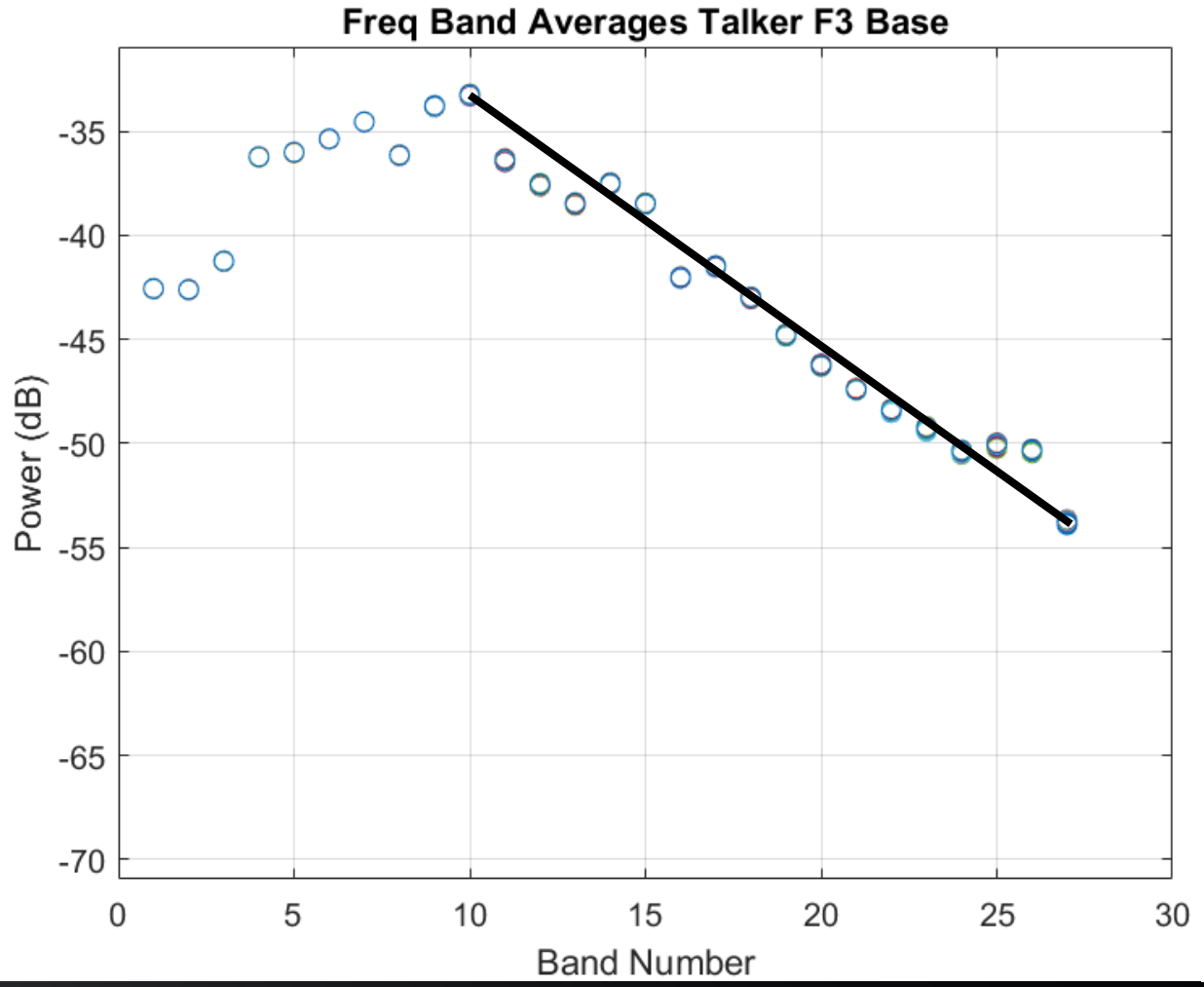
- ABC-MRT keywords
- Top 20 loud words based on dBA
- Four talkers, four clips
- Normalized to the average dBA

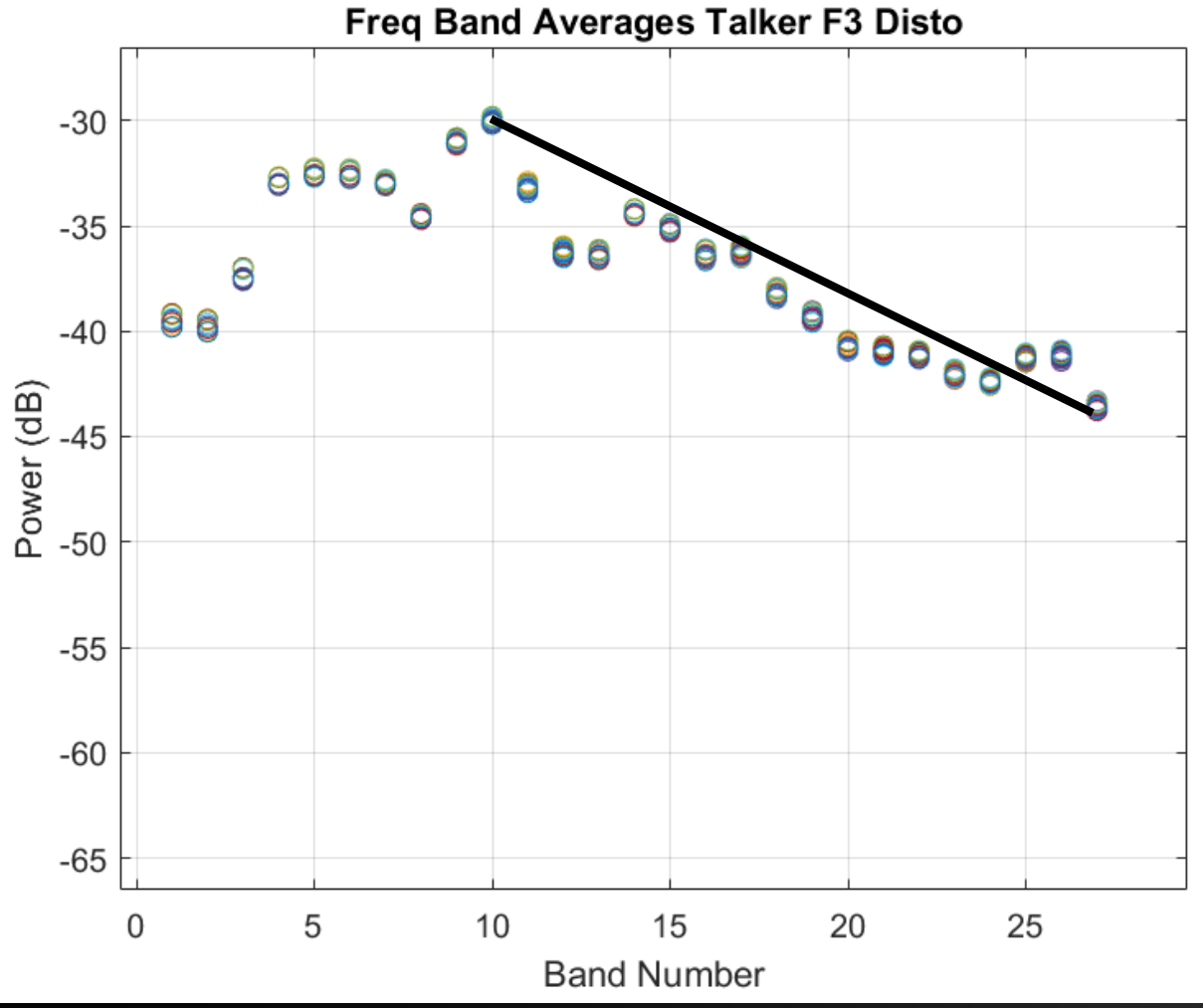


EXAMPLE AUDIO FILE

DISTORTION DETECTION METHOD
FREQUENCY SLOPE FIT (FSF)

1. Calculate periodogram to find spectrum power
2. Frequencies broken into bins
   - Articulation-Index bands
3. Calculate average power in each bin
4. Find the max of the first (lower) half of bins
5. Fit line from max power point through the higher frequency points, calculate slope
6. Divide slope of the recorded trial by the slope of transmitted audio slope value

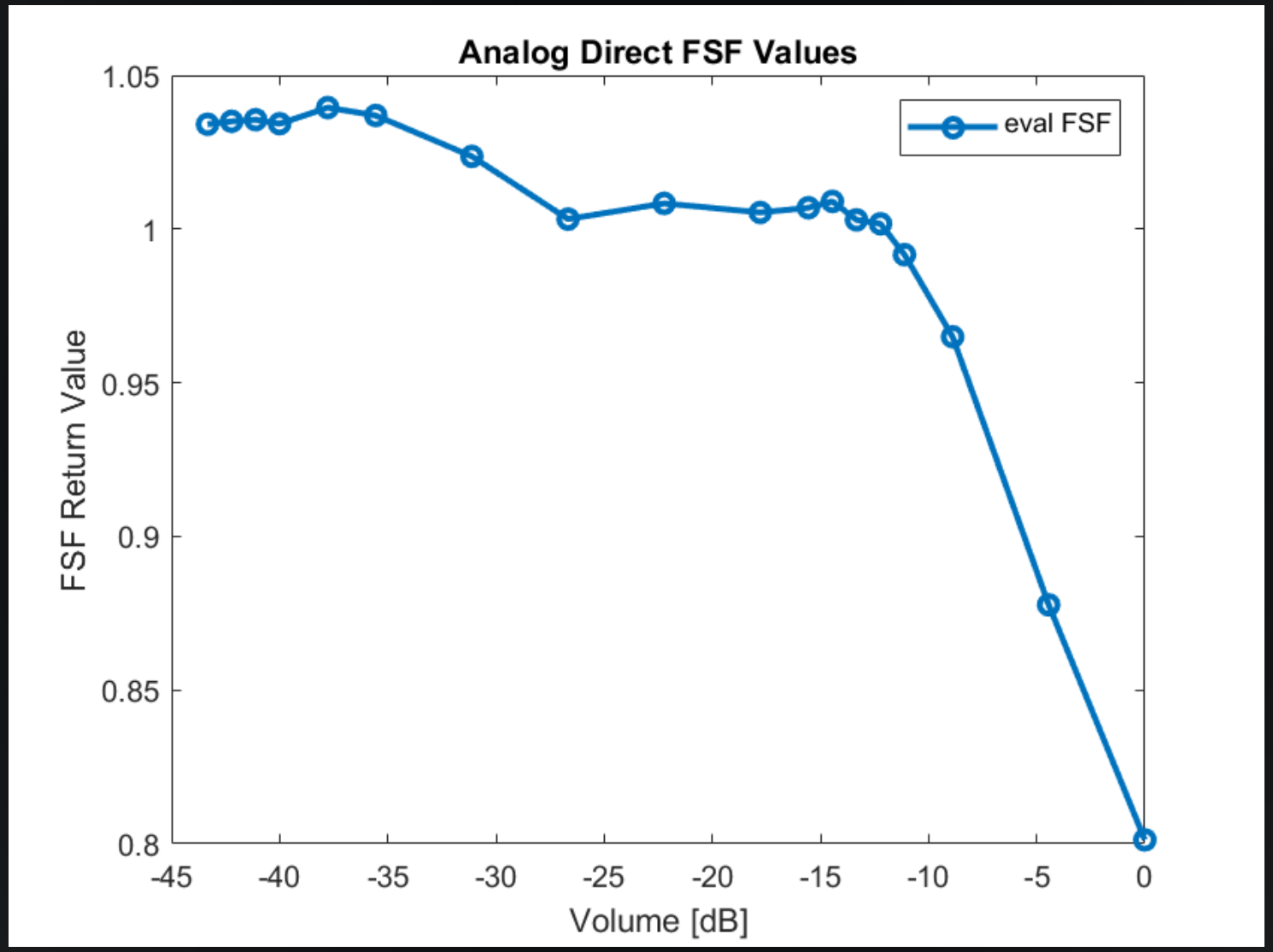




EXAMPLE SLOPE FIT

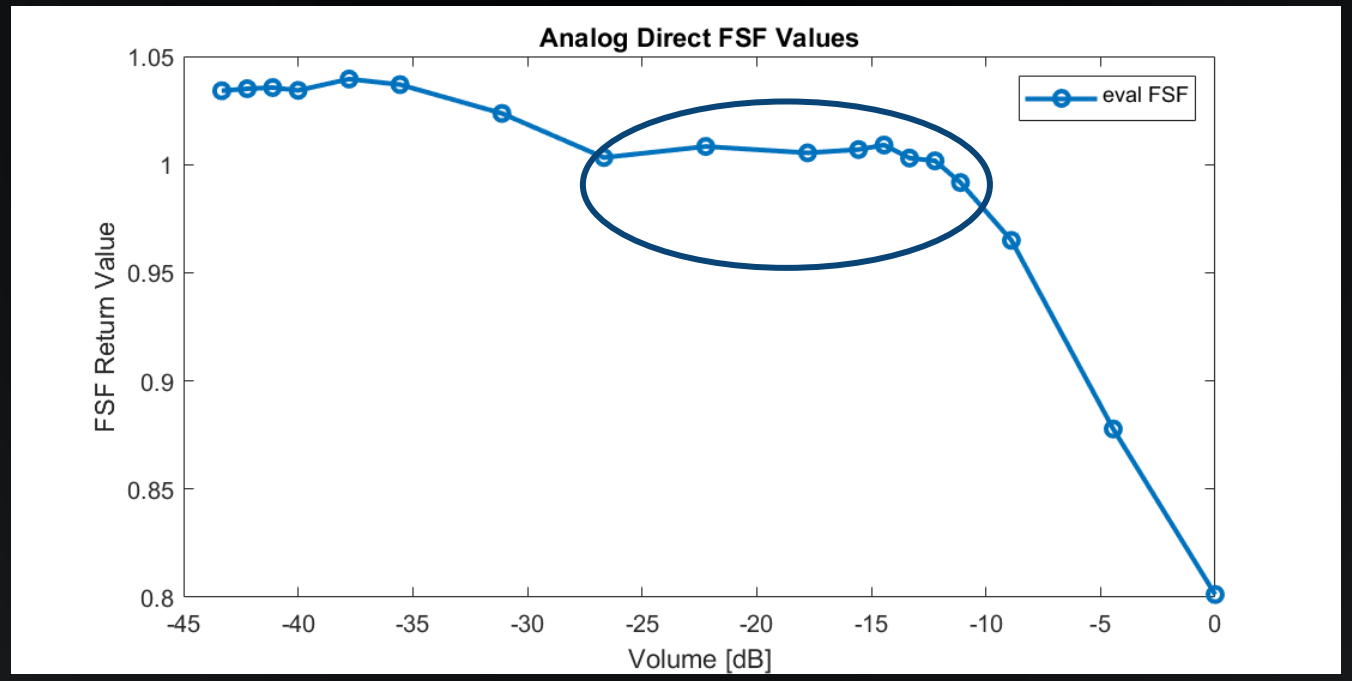
- The slope of this fit line is used for FSF scoring
- FSF = $\frac{slope\ of\ received\ audio}{slope\ of\ transmitted\ audio}$ (slope of received audio divided by slope of transmitted audio)

FREQUENCY SLOPE FIT (FSF) OUTPUT EXAMPLE



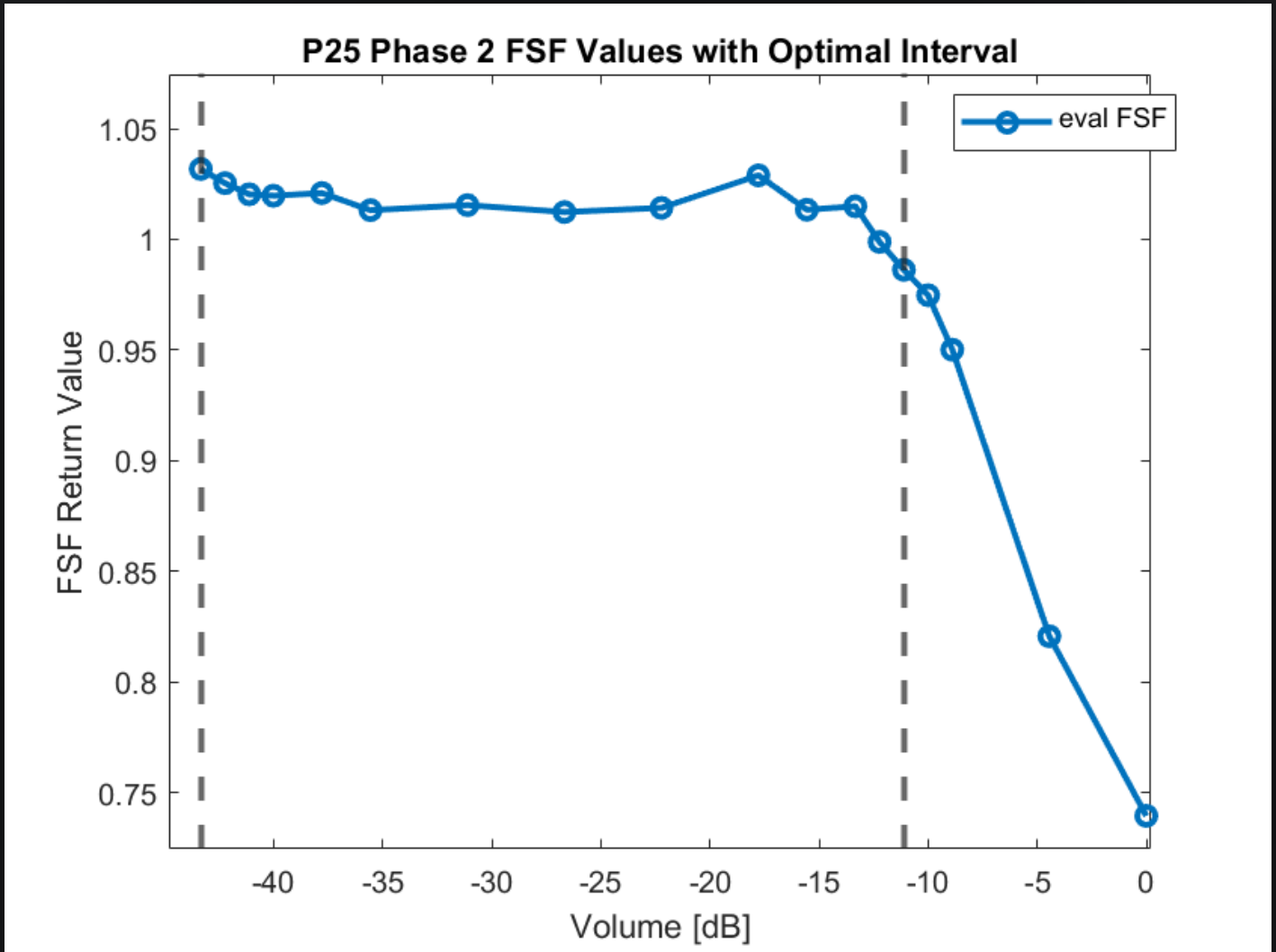
PLATEAU DETECTION

- There is a range of good/minimally distorted transmit volume settings
  - Flat region represents a minimally distorted range
  - Find the optimal volume by finding this plateau
  - Want to do this systematically, not just have users pick



OPTGRID GROUPING

- Start with initial points (transmit volume settings) to evaluate
- Group points by distribution
  - Approximate permutation test
  - Every successive point is checked against existing groups to see if there’s a match
  - Once points have been sorted into groups, the best is identified
  - This group is used for the new interval
  - Create grid, sample new points
  - Process continues until stopping condition is reached



OPTGRID TAKEAWAYS

- Region of FSF values that are close to optimal
- Robust to variation

MATHEMATICAL ANALYSIS

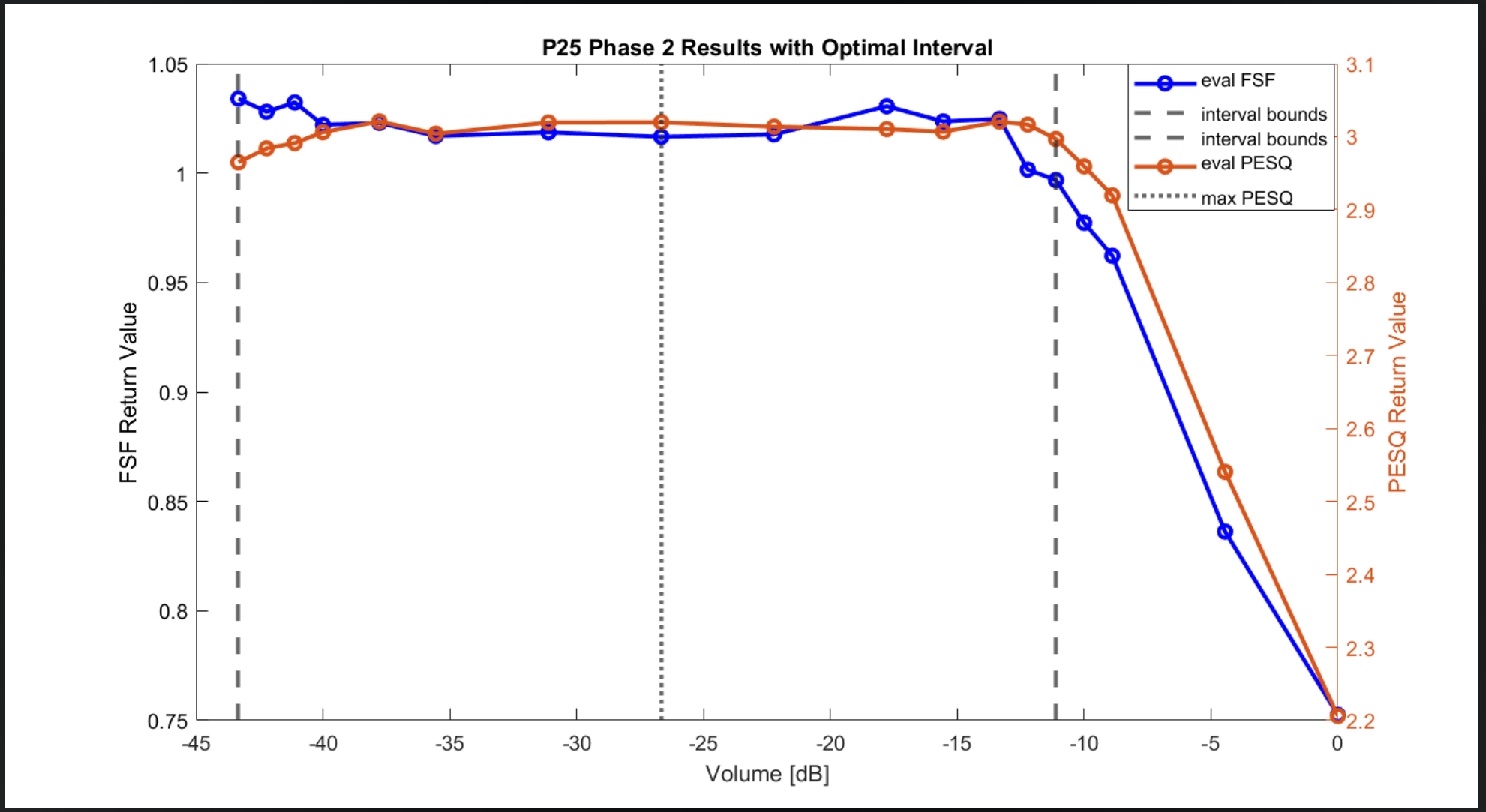
WHY FSF

- Characterizes distortion levels
  - Various sources of distortion
    - Harmonic
    - Overdriven
- Useful for characterizing lower quality at higher volumes
- Based on spectral analysis
- Alternative to speech quality metrics for targeted applications
  - Heavier distortion focus
- Does not require external packages or licenses

RELATING PESQ AND FSF

- Want to validate FSF as a useful measure
  - PESQ and FSF on different scales
  - Measure different signal qualities (distortion vs. quality)
- FSF drives plateau finding algorithm
  - Will FSF provide a reasonable plateau interval?
  - How do the scores compare on discovered interval?
- Interpretation
  - Will the FSF driven algorithm provide an interval at least as good as a PESQ driven algorithm?

RELATING PESQ AND FSF - EXAMPLE



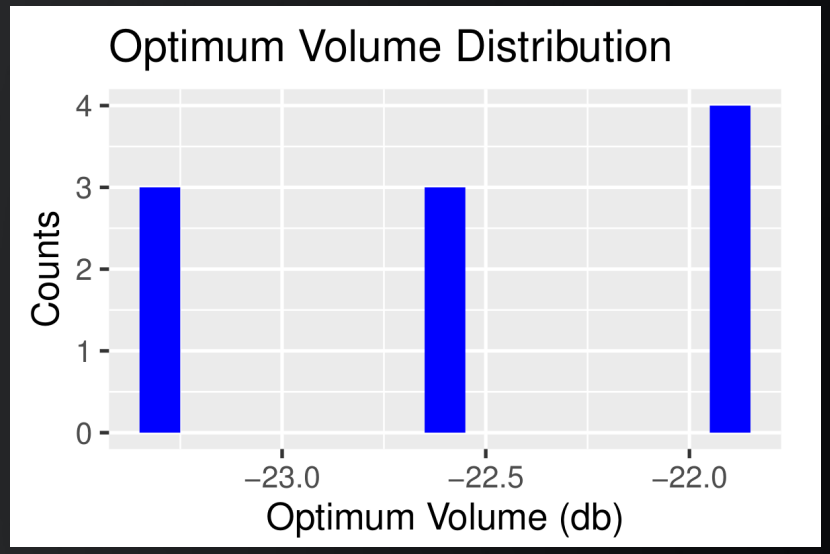
STABILITY ANALYSIS INTRODUCTION

- Optimum transmission volume calculated from plateau endpoints
- The stability of the selected interval endpoints, width, and final output value were calculated across data sets
  - Examine distribution of endpoints values. Determine stability on mean and variance statistics
  - Implications on stability of interval width/optimal volume
  - Performance varies with technology

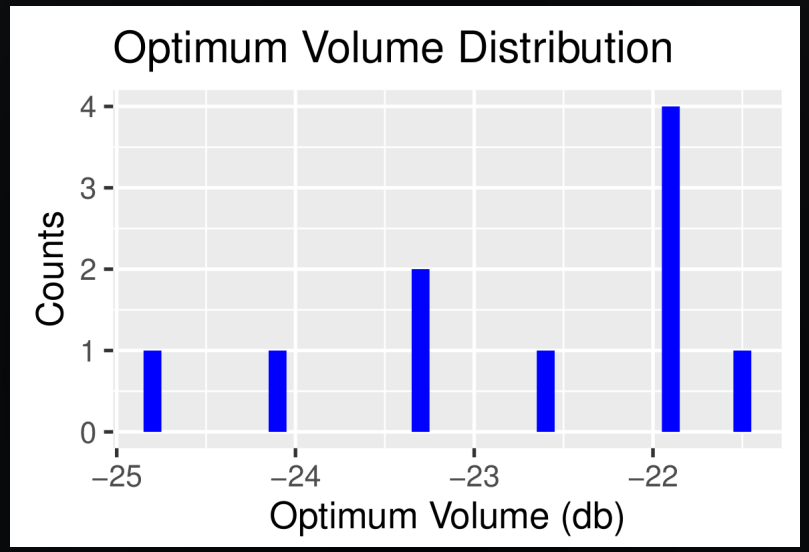
STABILITY ANALYSIS

- Stability within technology (P25 direct, P25 Phase 2, analog direct)
- More data for analog direct, characterize measurement uncertainty of our highest variance tech
- Stability across all technologies
  - Compare endpoint distributions across technology
  - Varying performance
  - This is expected; Analog Direct vs. P25 technologies have different distortion profiles

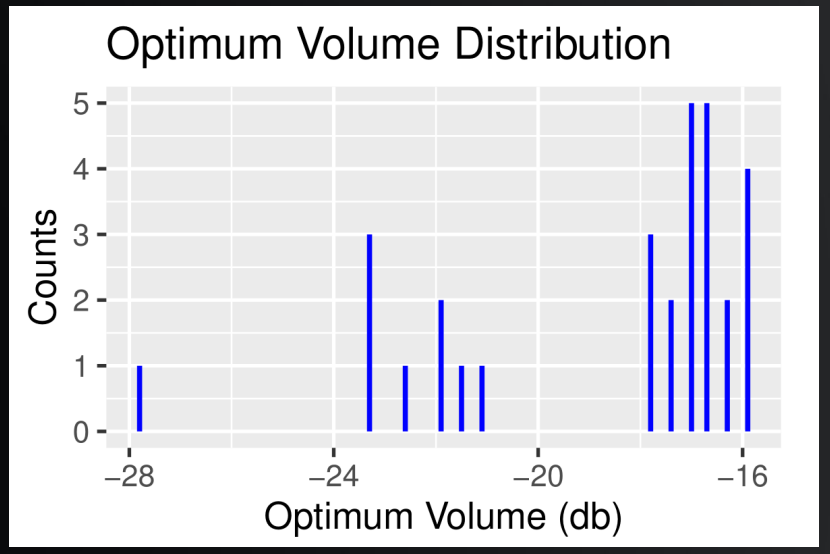
OPTIMUM VOLUME DISTRIBUTION



Analog Direct



P25 Phase 2



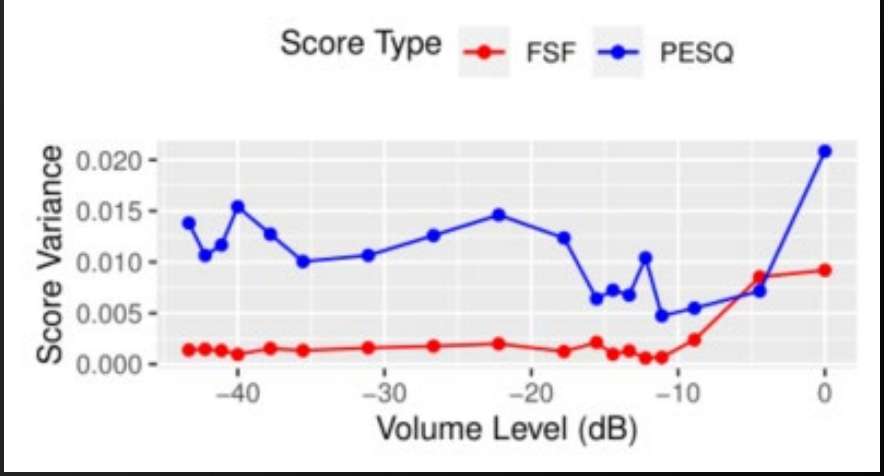
P25 Direct

STABILITY ANALYSIS EXAMPLES

- Example data across technologies
  - Upper bound clustered near bend in the curve
  - Lower bound dips below -40 dB due to interpolation
- Lower bound corresponds to distortion increase
  - Reflected in FSF score variance
  - PESQ score variance parallels FSF

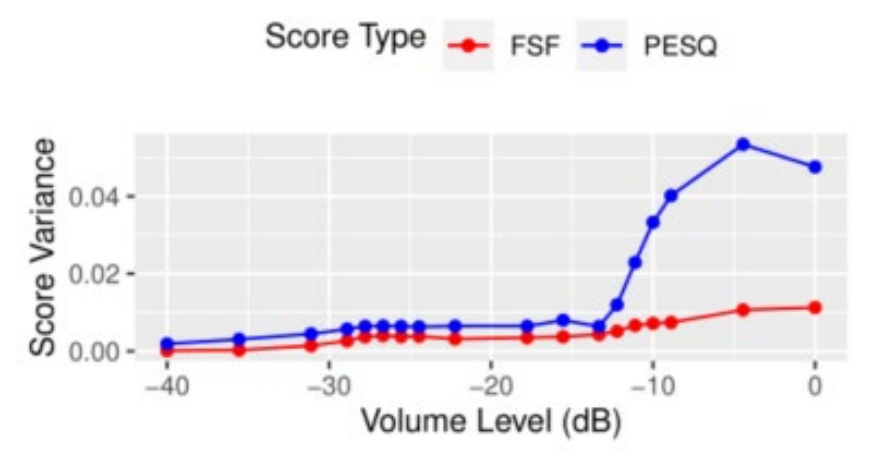
Technology	Lower Bound (dB)	Upper Bound (dB)
Analog Direct	-33.52 ± 2.27	-11.22 ± 0.94
P25 Direct	-43.33 ± 0.47	-12.11± 0.84
P25 Phase 2	-43.00 ± 0.65	-12.55 ± 1.05

STABILITY ANALYSIS – VARIANCE ACROSS TECHNOLOGIES



P25 Direct

PESQ variance dominates FSF variance until ~ -5 dB



Analog Direct

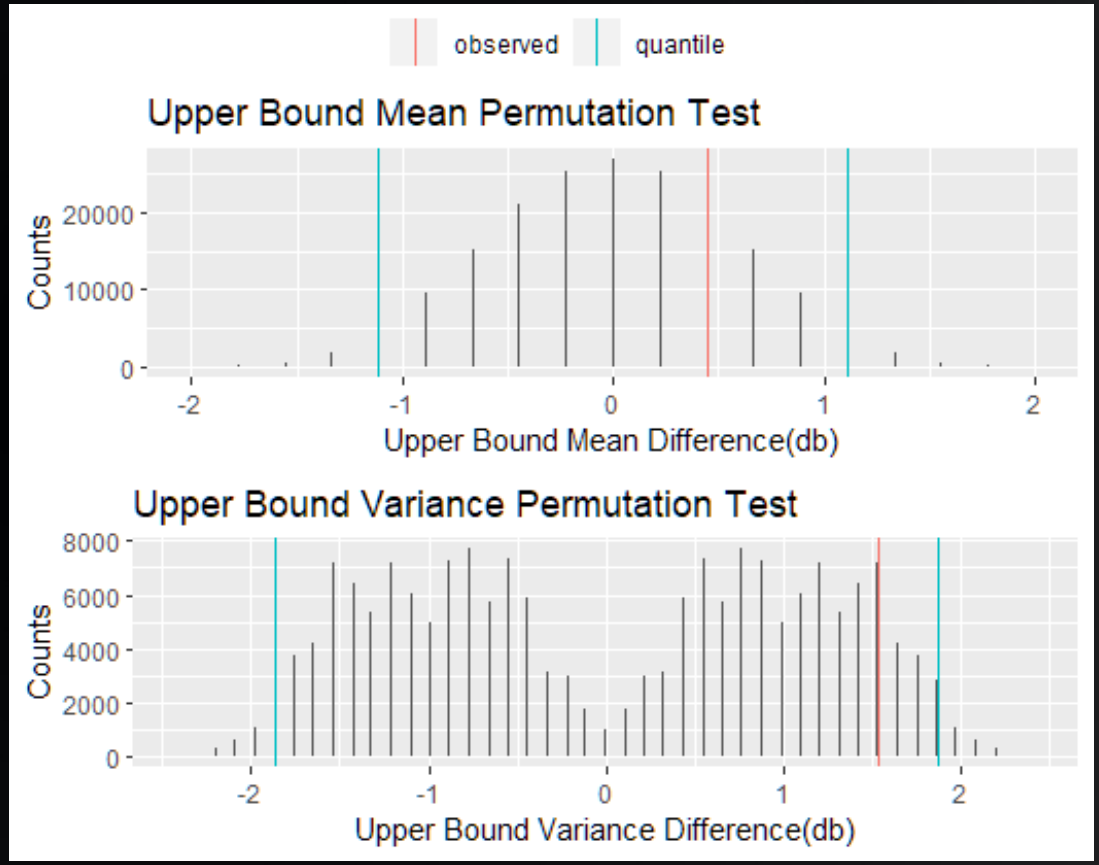
PESQ variance dominates FSF variance over all volume levels. Spikes after around ~ -12 dB.

INTERVAL STABILITY ANALYSIS

P25 Direct vs. P25 Phase 2

Examples of permutation tests for upper bound mean and variance.

Observed values lie within the confidence intervals, demonstrating statistical equivalence.

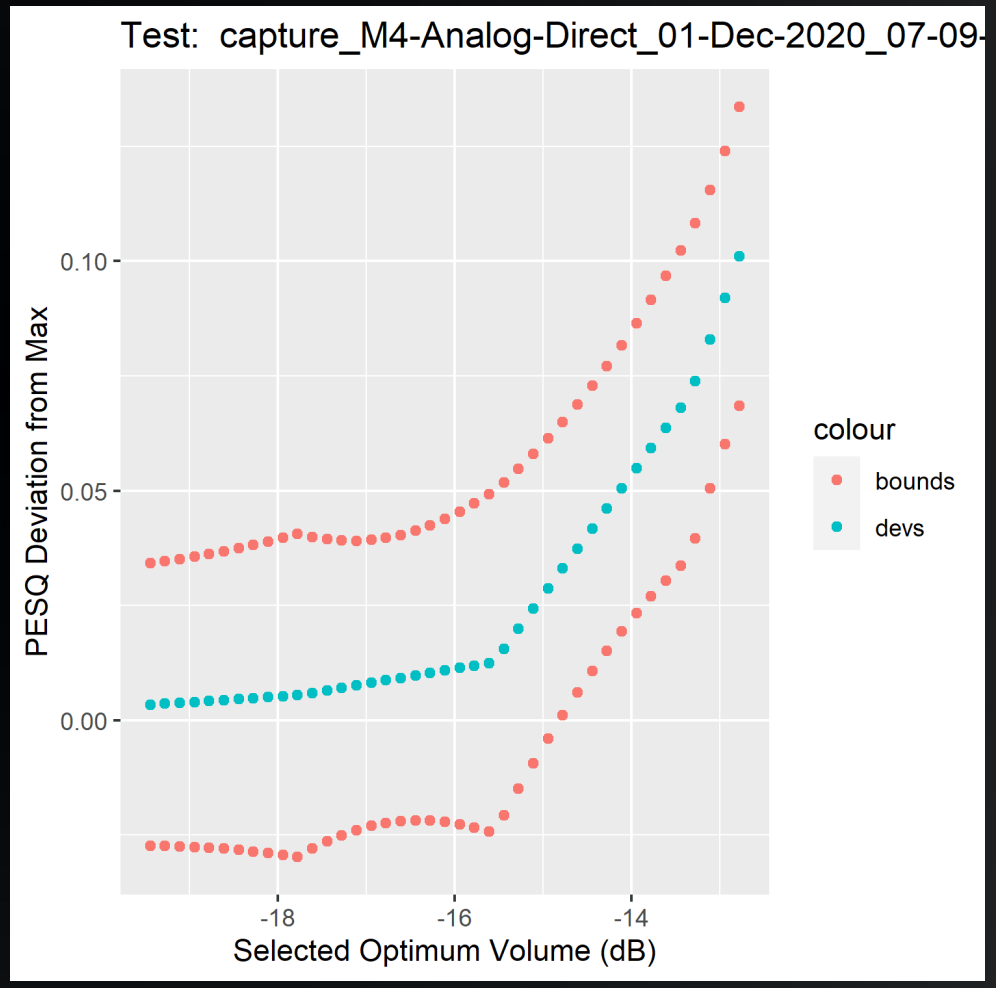


SELECTING THE OPTIMAL SETTING

- Wanted to avoid edge cases, started with interval midpoint
- Refined optimal point based on analysis, changed to 0.8
  - Use overlapping confidence intervals to determine range of statistically equivalent to optimum value weighting
  - Take the maximum of these, because higher volumes are preferable
  - Higher end of interval more stable than lower end, should have a higher weight in optimal volume determination
  - Need to account for linear interpolation of confidence intervals of PESQ scores

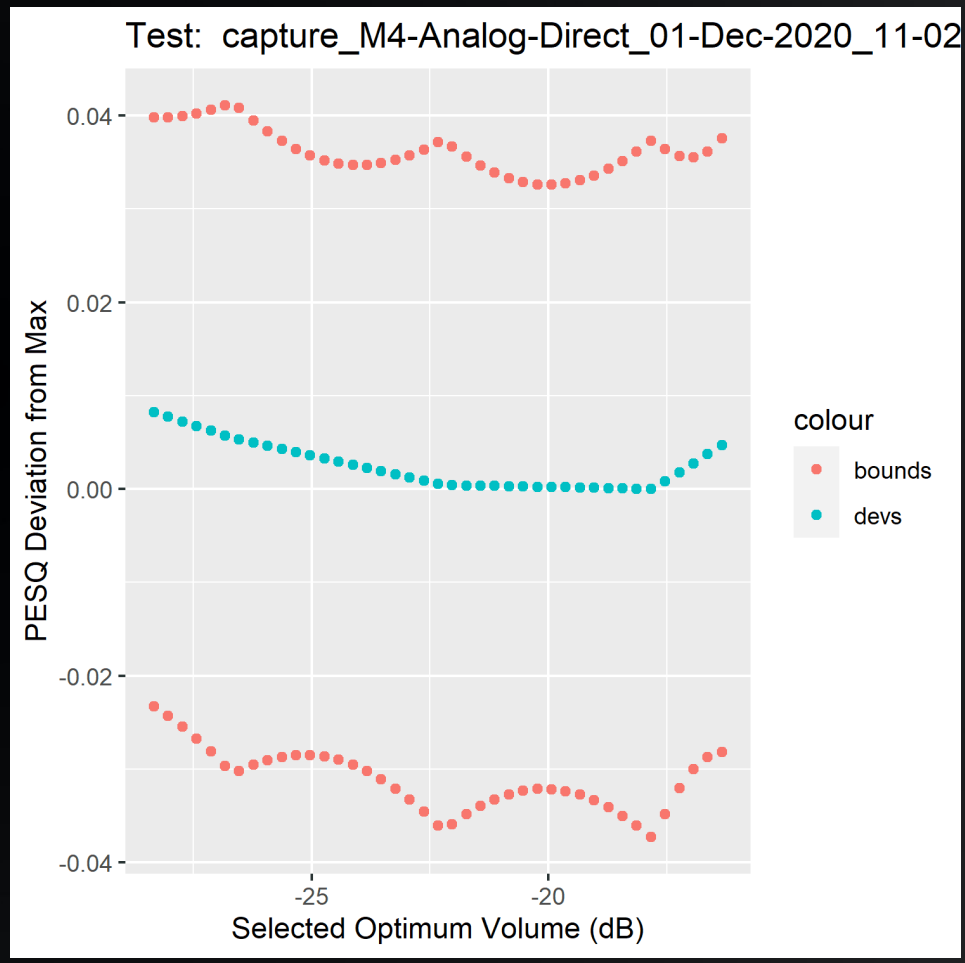
DETERMINE OPTIMAL VOLUME WEIGHTING

- Basic idea
  - Is there ever a lower bound higher than an upper bound?
  - In this case, yes
  - Multiple curve types



DETERMINE OPTIMAL VOLUME WEIGHTING

- Data from analog direct
- Two types of curve seen
- In second graph, all intervals overlap
- In first graph, later points don’t overlap with earlier points
- Parabolic bounds due to uncertainty propagation



UNCERTAINTY CALCULATIONS

- Optimum volume
  - Weighted average of interval endpoints
  - Used weight determined by statistical test
  - Usual propagation of uncertainty
- Overlapping confidence intervals used as statistical test
  - More rigorous tests exist, not necessary, however

Technology	Optimal Volume (dB)	Uncertainty (dB)
Analog Direct	-15.6815	3.6147
P25 Direct	-18.3555	1.2612
P25 Phase 2	-17.5278	1.7123

RECAP

- Optimal volume setting package
  - FSF
    - Used to measure distortion
    - Uses transmitted audio as reference
  - OptGrid
    - Used to detect stable regions of settings
    - This interval is used to select the optimal setting
- Understand how the package is used to determine optimal transmit volume settings
- Understand analysis used to determine the optimal transmit volume setting

MAIN TAKEAWAYS

- Developed reliable method to determine distortion levels caused by transmit device volume settings
  - Distortion from overdriving speech into a transmit device and how that propagates through the communications system
  - Can determine settings to minimize this distortion contributor
- Use settings in MCV measurements
  - Improved consistency, comparability, repeatability
- Future work
  - Paper, code, data to be published
  - Convert to Python


THANK YOU
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