Links between concert hall geometry, objective parameters, and sound quality

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For decades, the design of concert halls was driven by considerations of time history alone (T60, C80, ITDG), and as a result, little importance was attached to room geometry. The subjective importance of binaural dissimilarity has been a strong, though often simplistic, influence on recent designs. While listening experience has shown which fundamental room forms sound better than others, computer modeling and statistical analysis have enabled systematic investigation of the degree to which the geometry affects the sound. Using simple parametric models, this study will investigate effects of surface parallelism, concavity, and convexity on spatial and monaural objective acoustical parameters and on essential subjective attributes.

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Invited paper 2aAAa5, 16 March 1999

Aims

- To investigate some basic geometric parameters that we encounter in hall design and the objective and subjective differences as they are varied.

- To use trends among shapes as a means for greater understanding.

Architectural Scales

Large Scale	**Size, Dimension** **Audience capacity**
Medium Scale	**Gross Geometry** **Surface Shaping**
Small Scale	**Detail, Textures, Finishes**

Gross Scale: Some Simple Rules of Thumb

Quantitative

- SPL and subjective loudness decrease with greater audience area
- Duration of reverberant decay increases with increased ceiling height

Qualitative

- C80 and subjective clarity can be increased in a tall space with the addition of suspended surfaces

Room Shape has great influence on….

Spatial Qualities	Envelopment, Spaciousness IACC, LF
Mono Qualities	Subjective Clarity, Reverberance, Loudness EDT, T60, C80, G

Quantifying Effects of Geometry on Sound

We know many of the general principles, but

- How much does the sound depend on geometry?
  - Subjectively?
  - Objectively?
- What are the additional / unexpected effects?

--> Modelling and auralisation

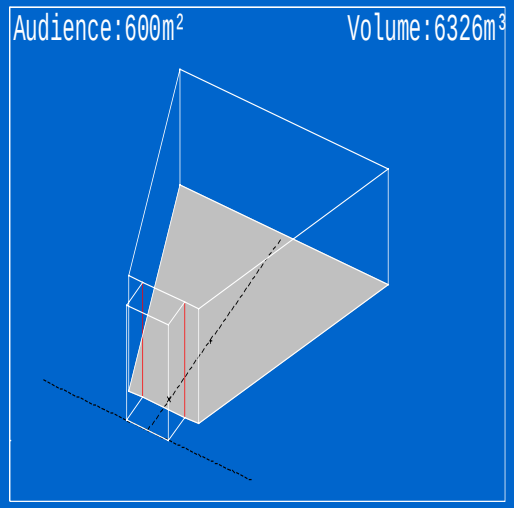
Computer Model Case Studies: Simple variations on a shoebox

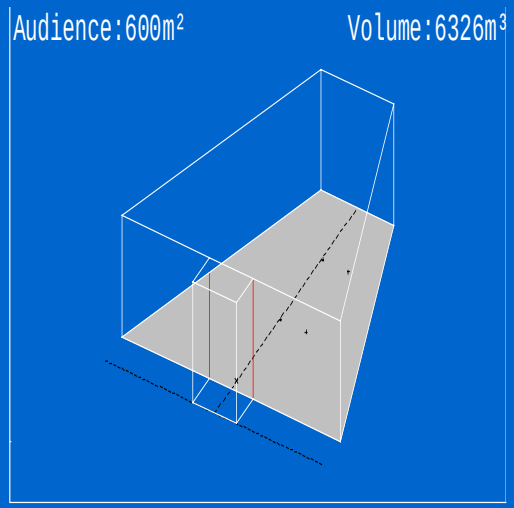
- plan shape
- ceiling pitch
- seating slope
- hall width

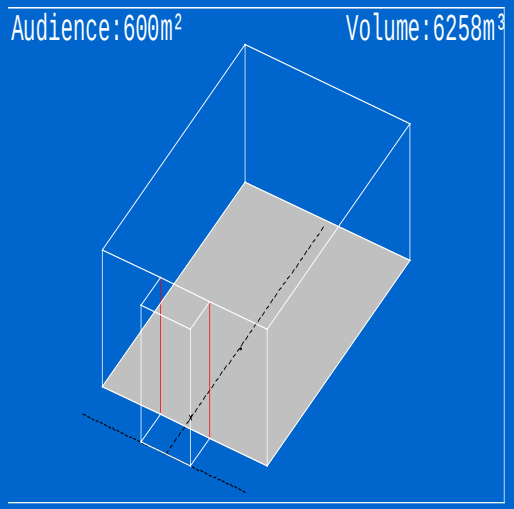
Procedure

- Modelling software: CATT 7.0 - beam tracing with frequency-dependent surface diffusion
- Compared results produced by CATT
- Listened to results enough to give a qualitative indication of the degree of audibility

Plan Variation: Fan, Shoebox, Reverse Fan

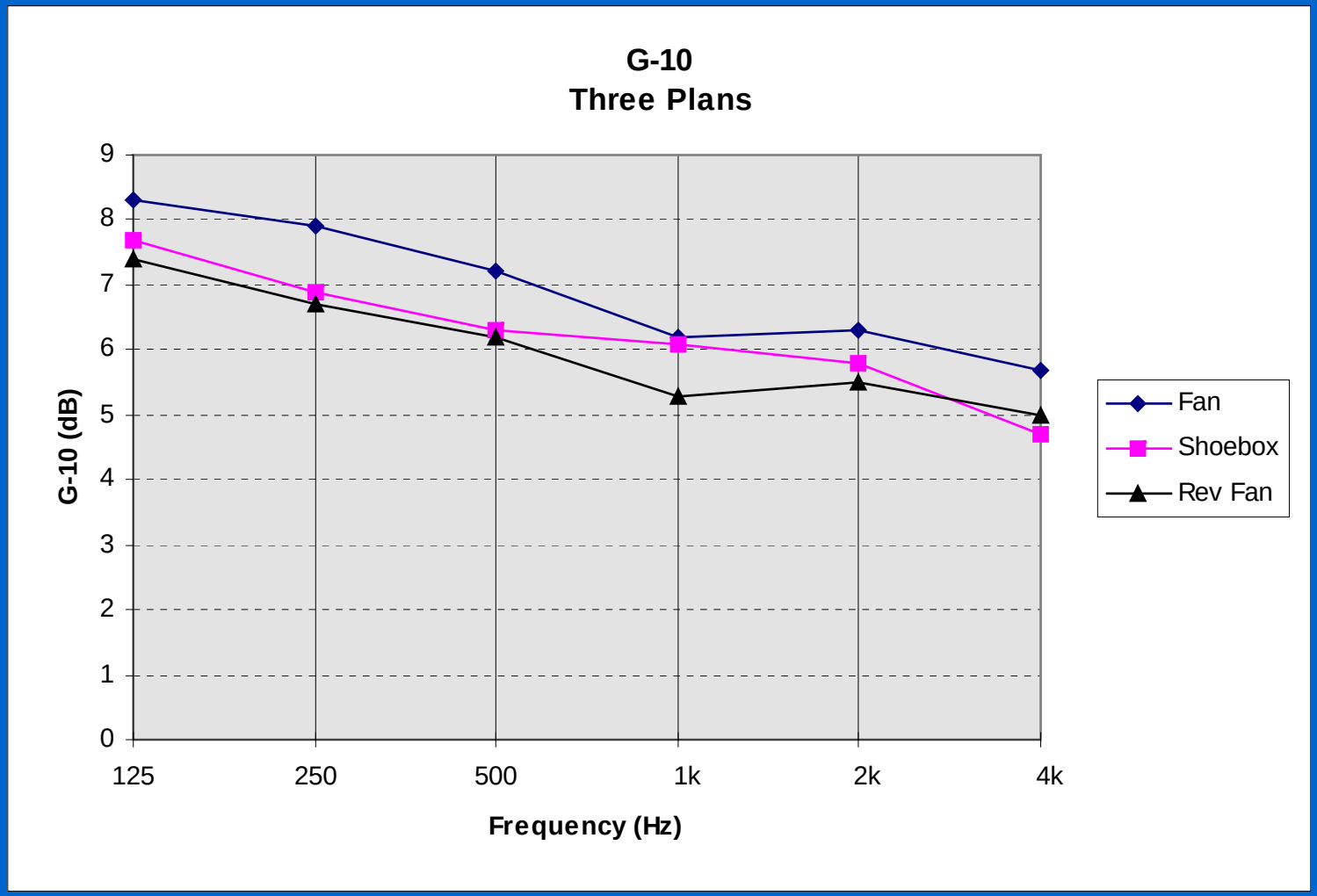




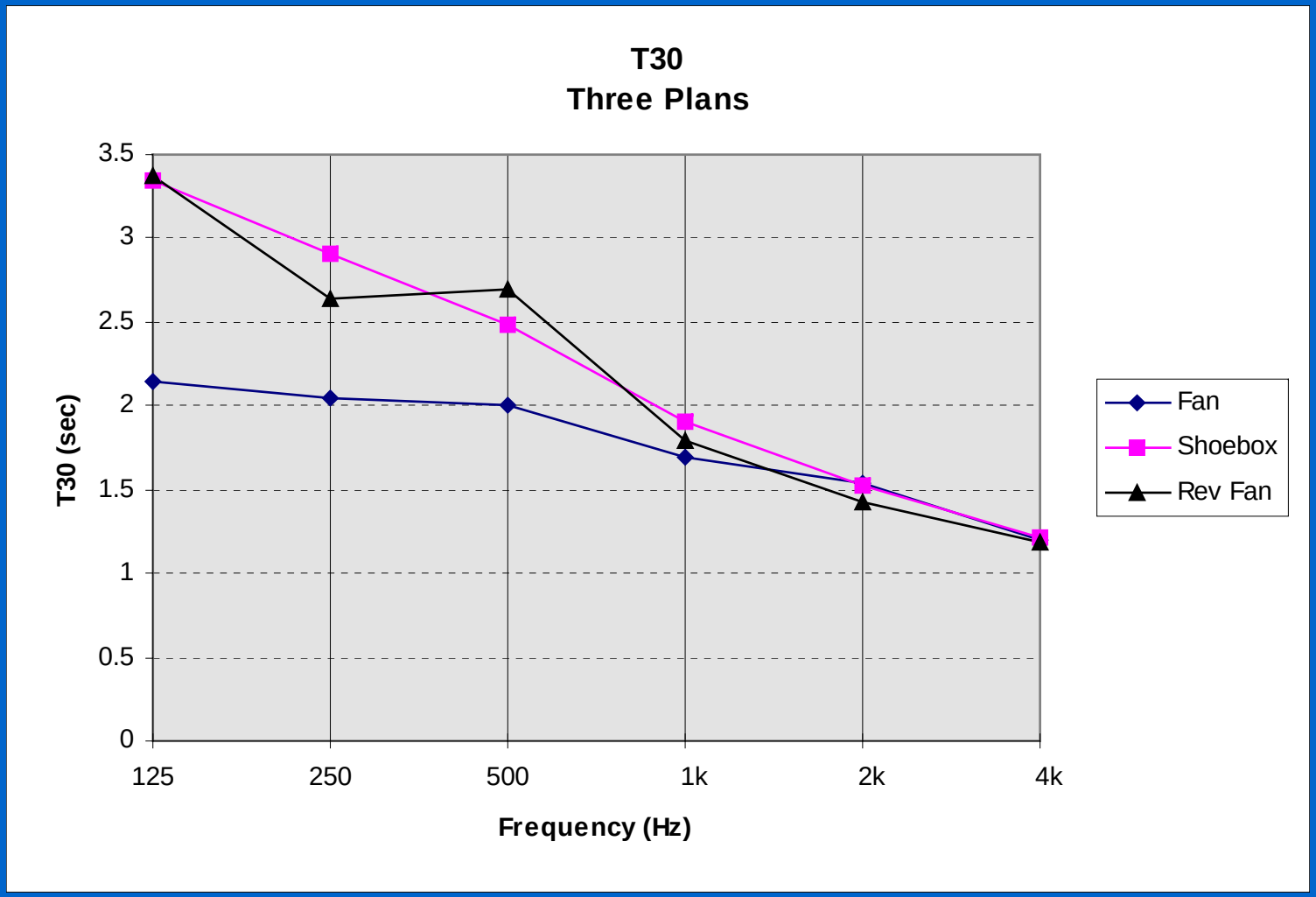


L = 30 m, W = 20 m H = 10 m
Walls of fans pivoted to achieve the same floor area as shoebox.
Audience absorption on floor.
Plaster walls with moderate diffusion.

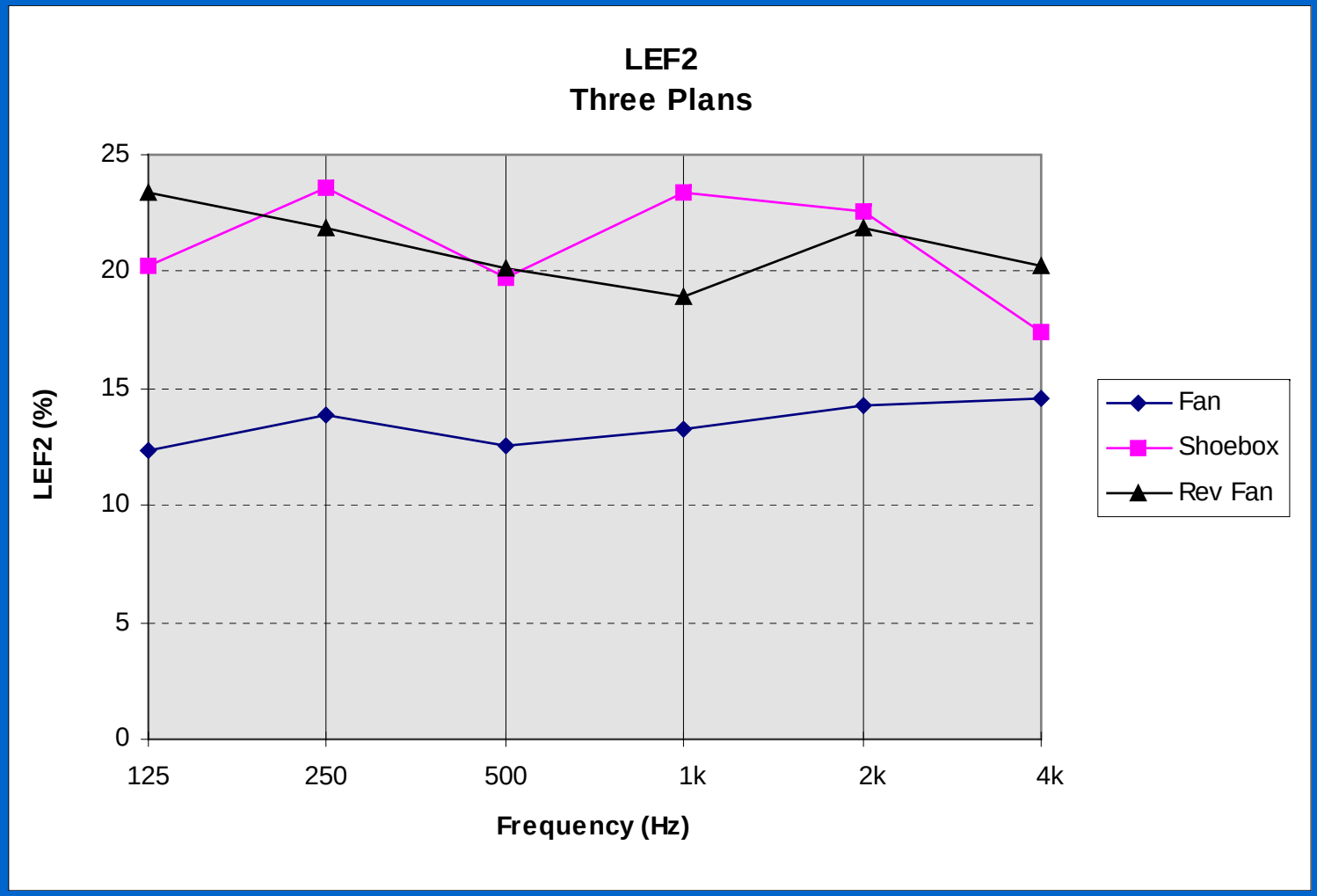
G-10 Three Plans: Fan, Shoebox, Reverse Fan



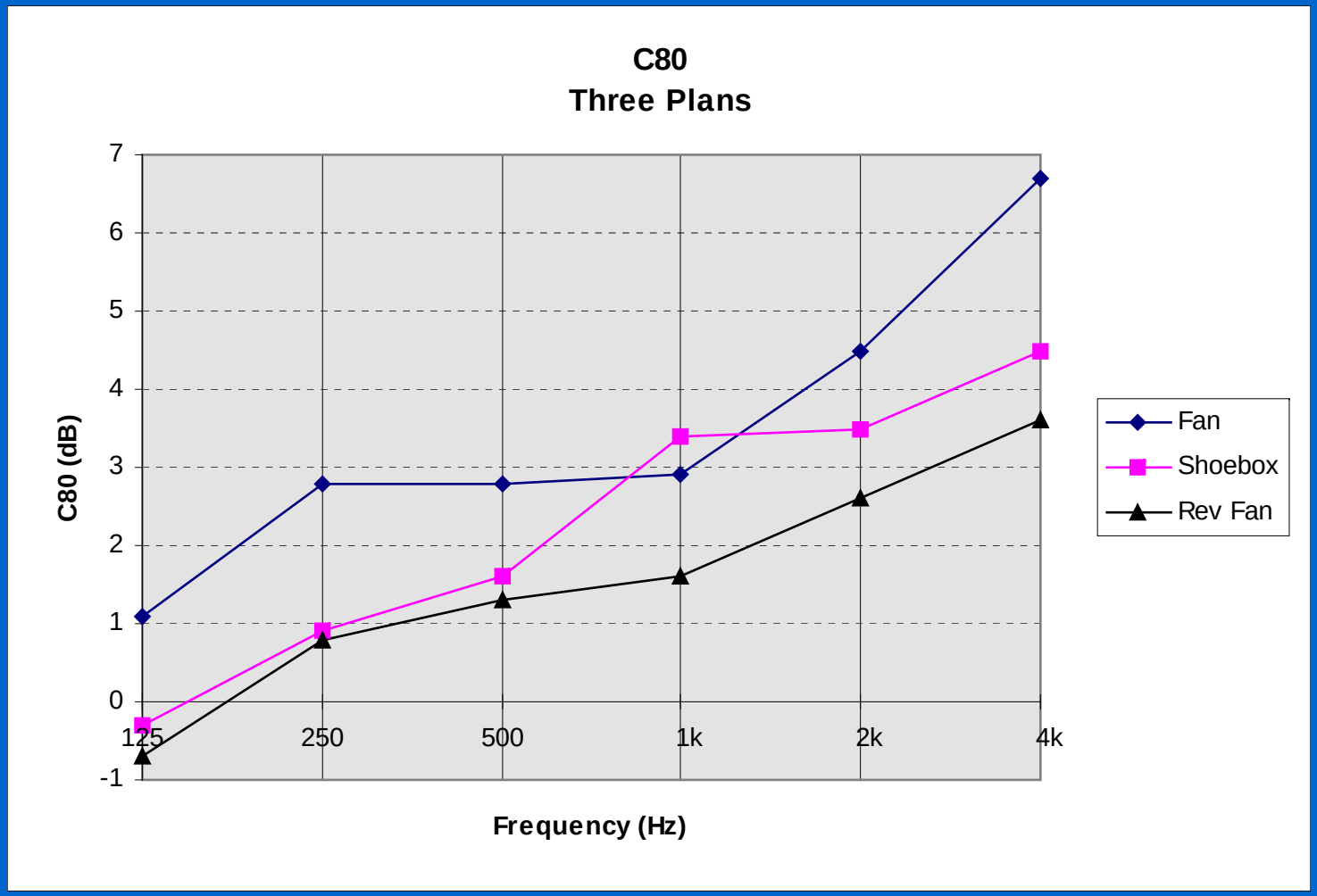
T30 Three Plans: Fan, Shoebox, Reverse Fan



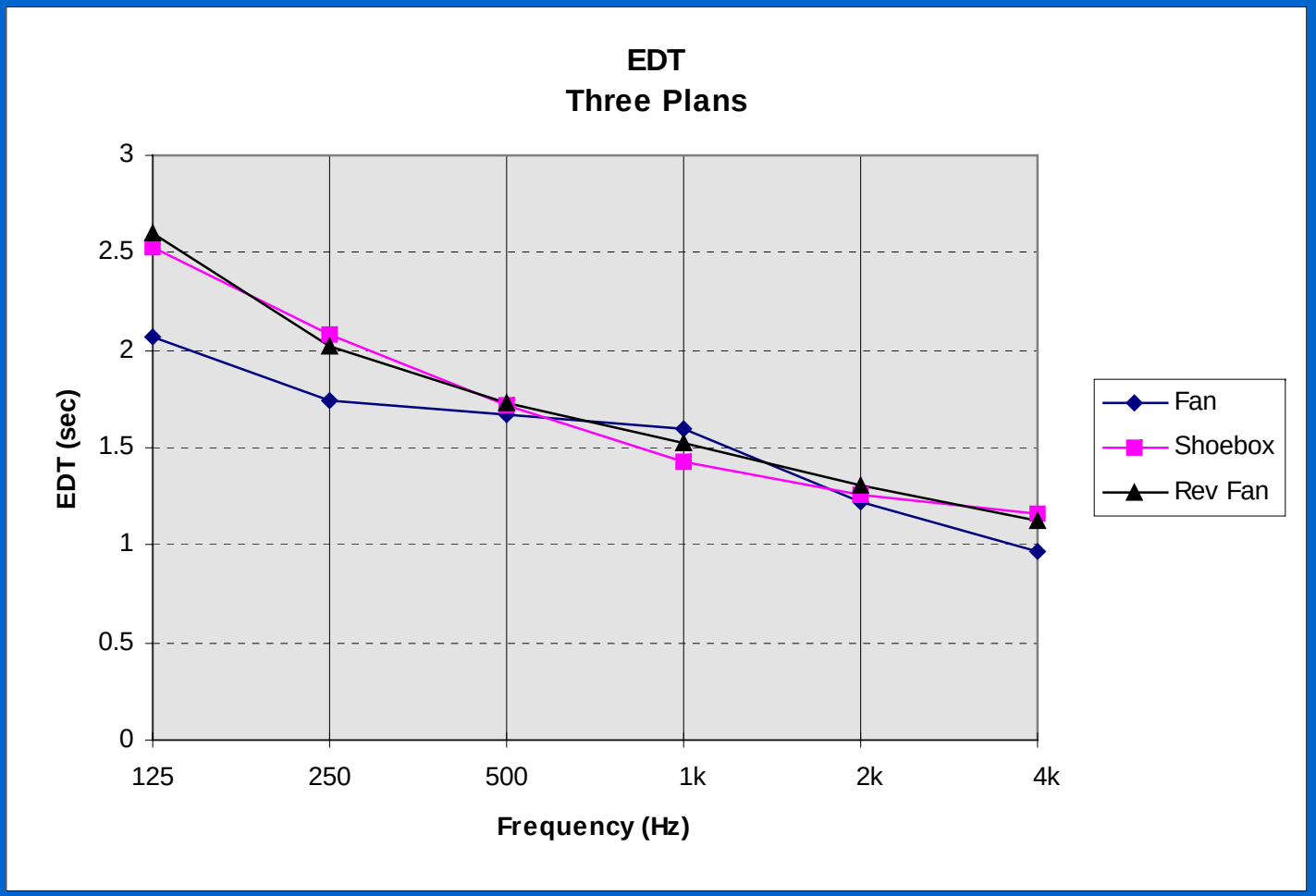
LEF2 Three Plans: Fan, Shoebox, Reverse Fan



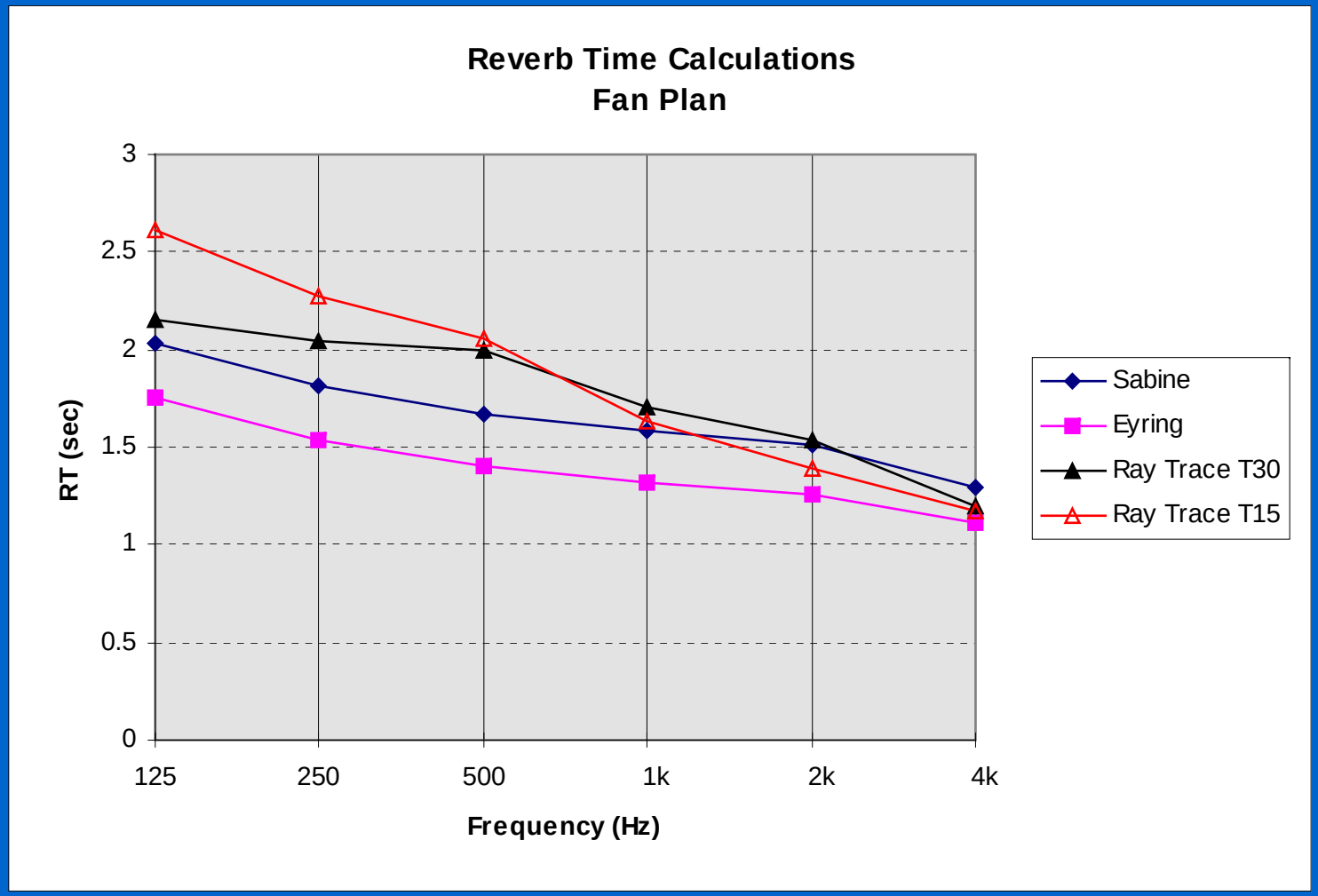
C80 Three Plans: Fan, Shoebox, Reverse Fan



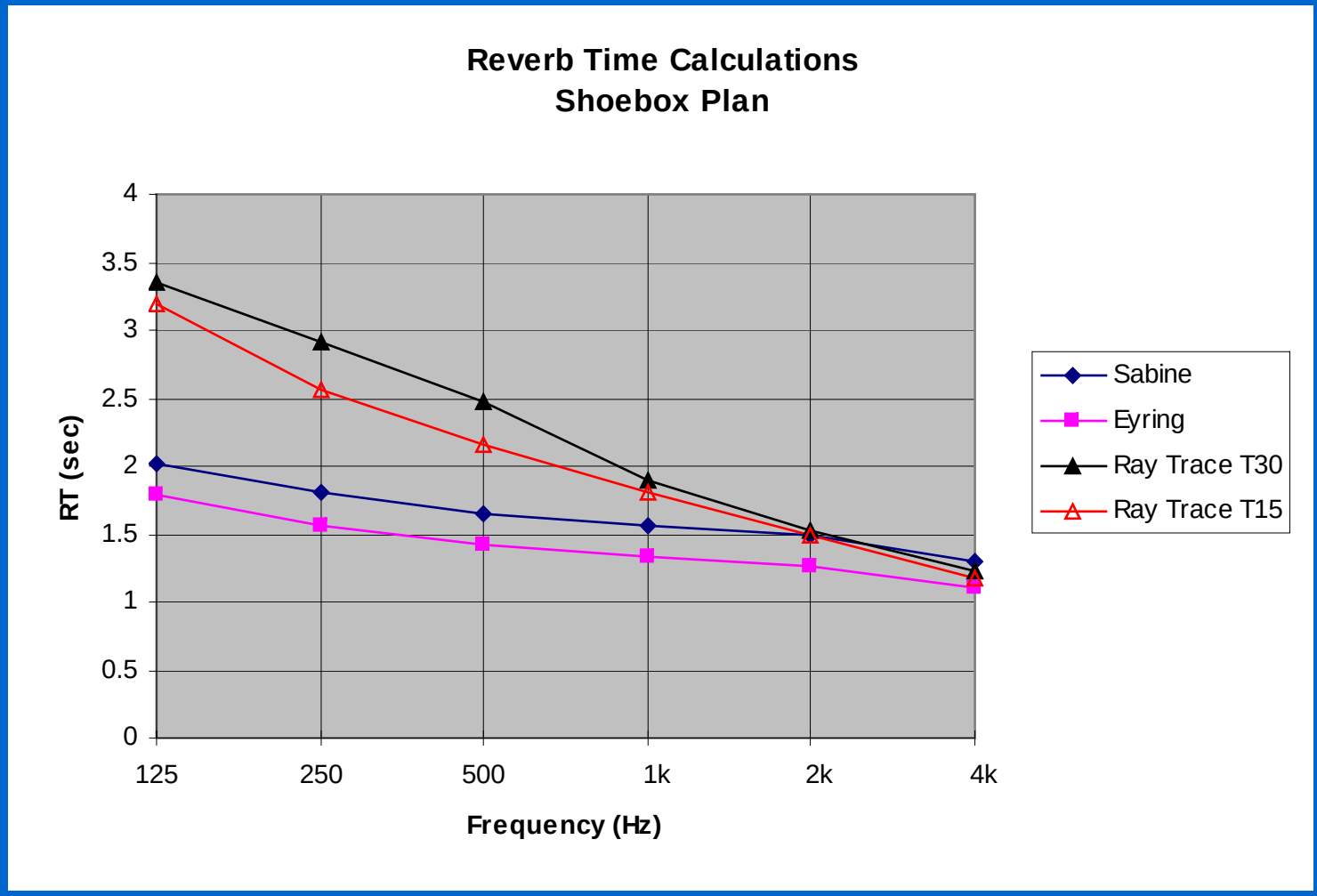
EDT Three plans: Fan, Shoebox, Reverse Fan



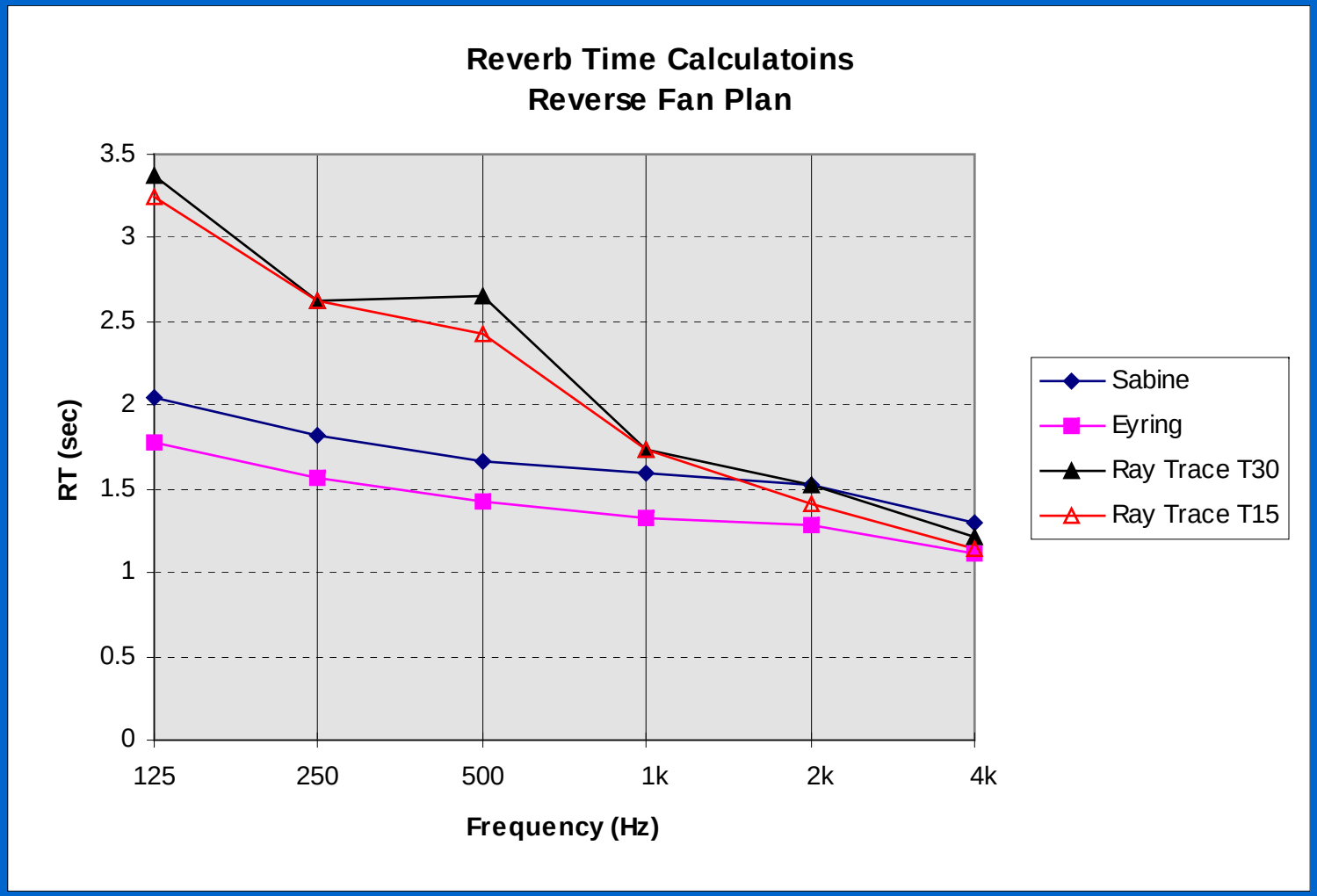
RT Comparisions: Fan Plan



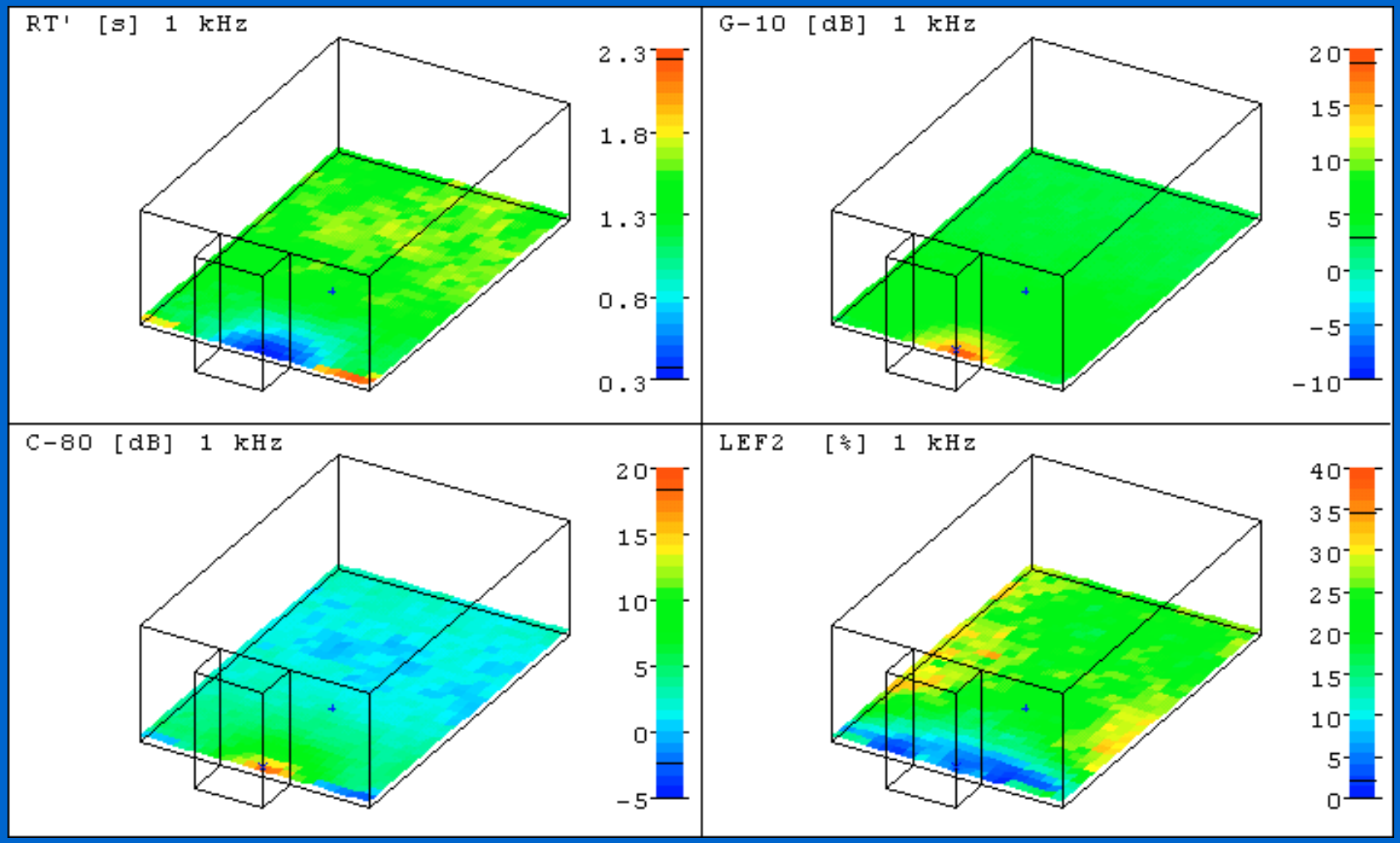
Reverb Time Comparisons: Shoebox Plan



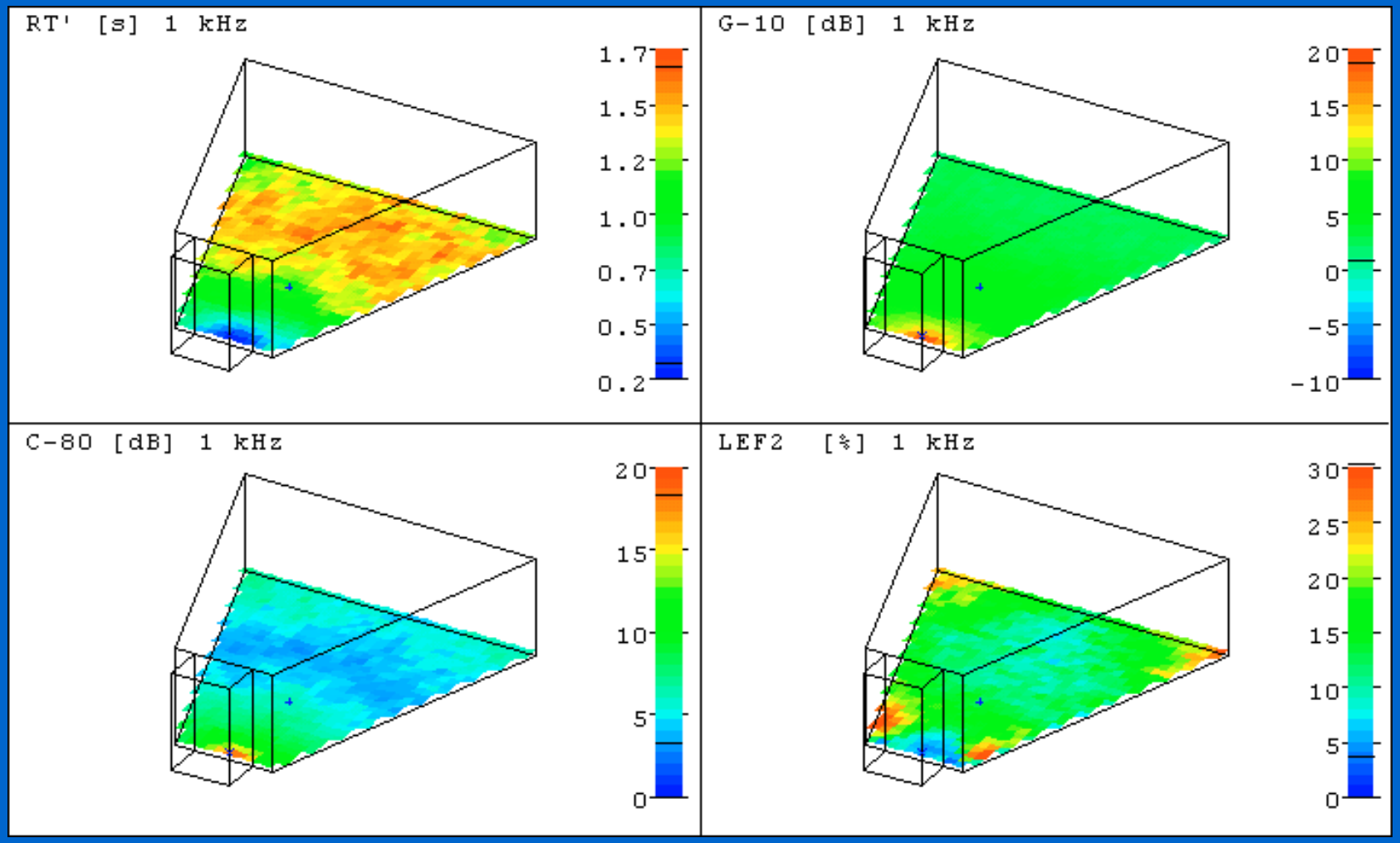
Reverb Time Comparison: Reverse Fan Plan



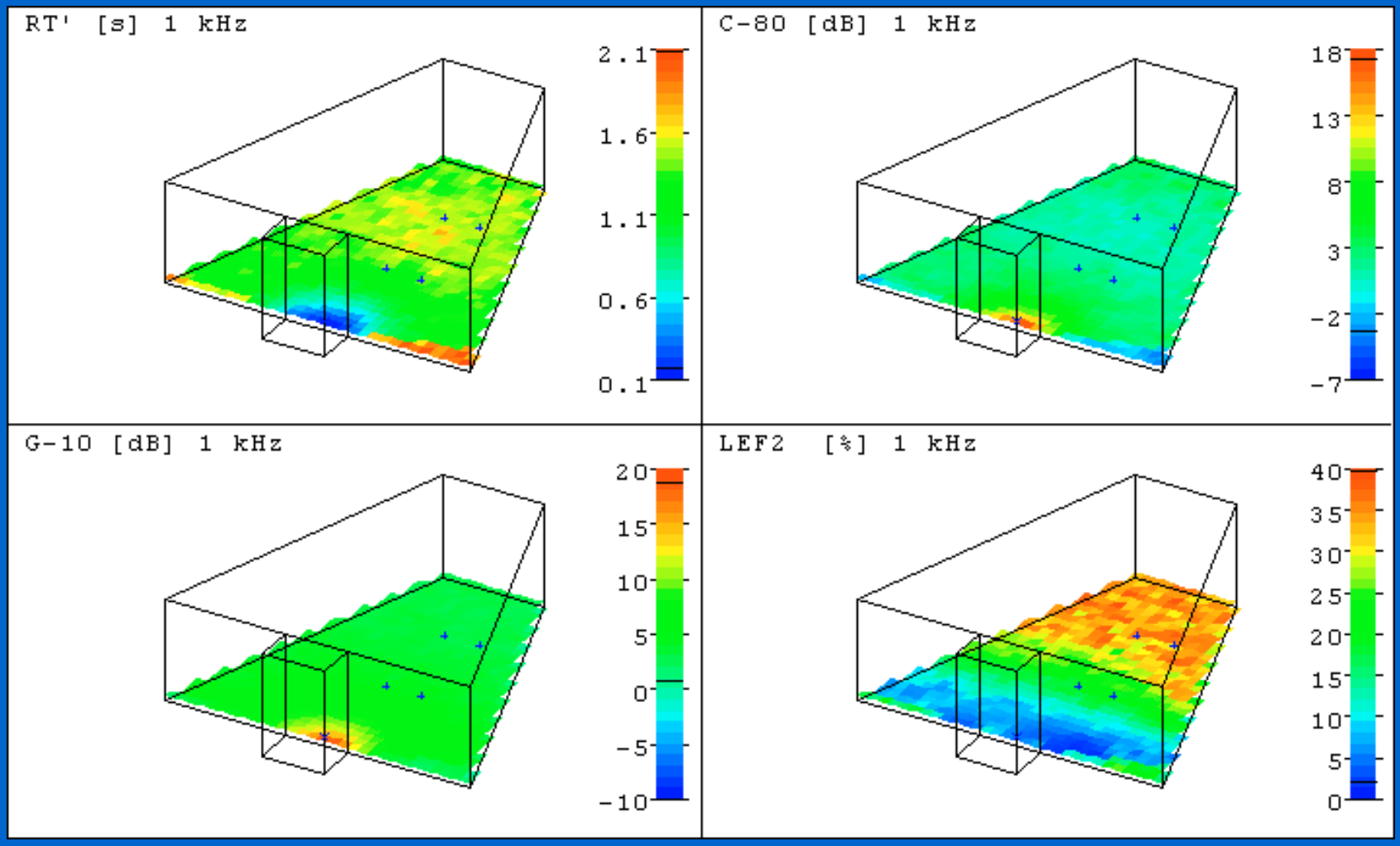
Shoebox: Spatial Distribution



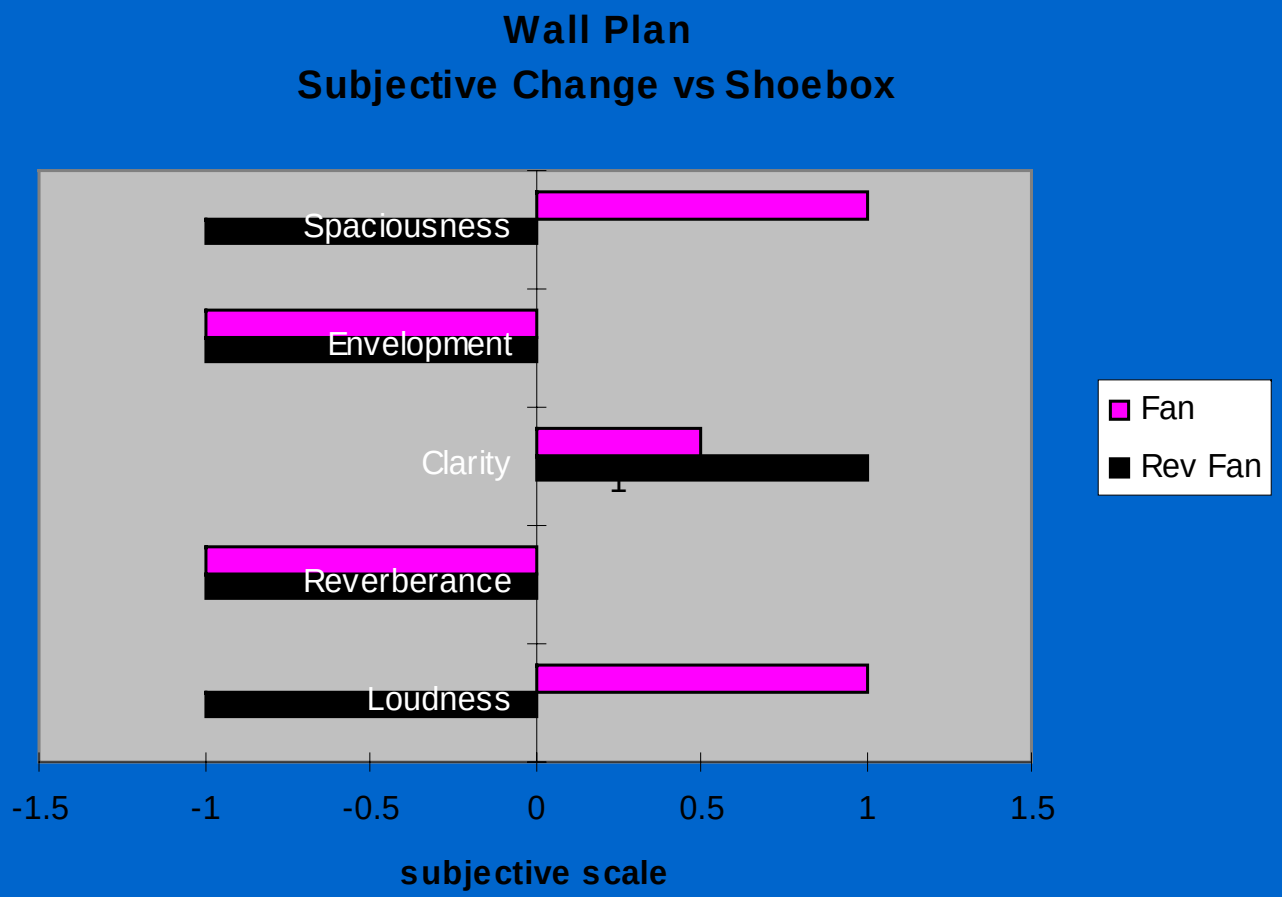
Fan Plan: Spatial Distribution



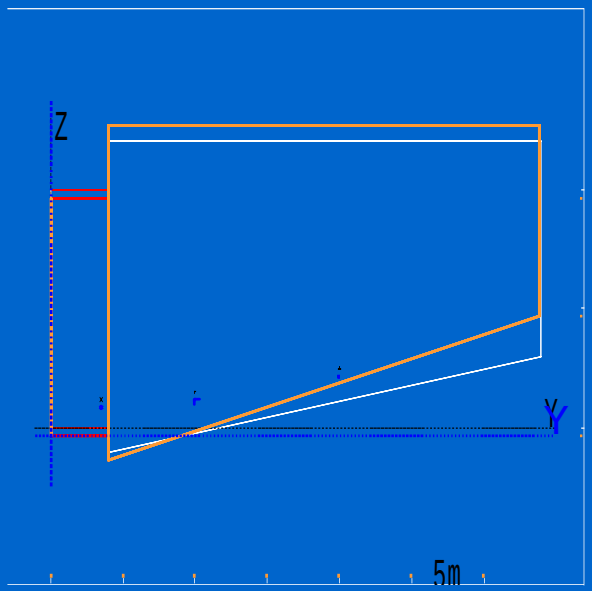
Reverse Fan: Spatial Distribution

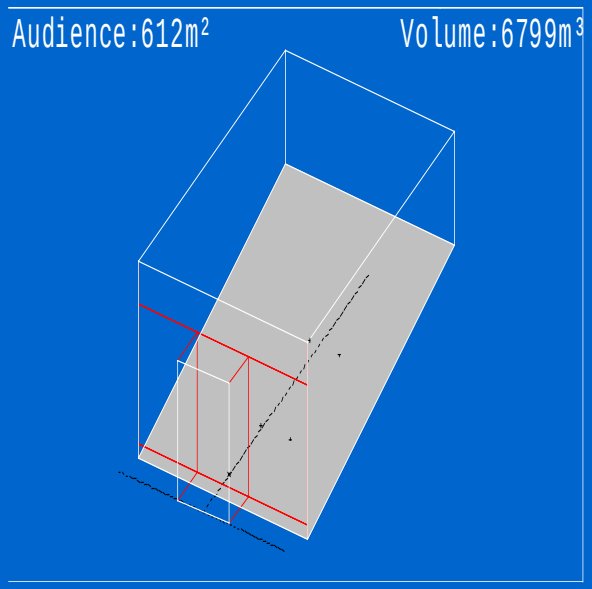


Wall Plan Subjective vs Shoebox



Floor Rake (Slope) Geometries

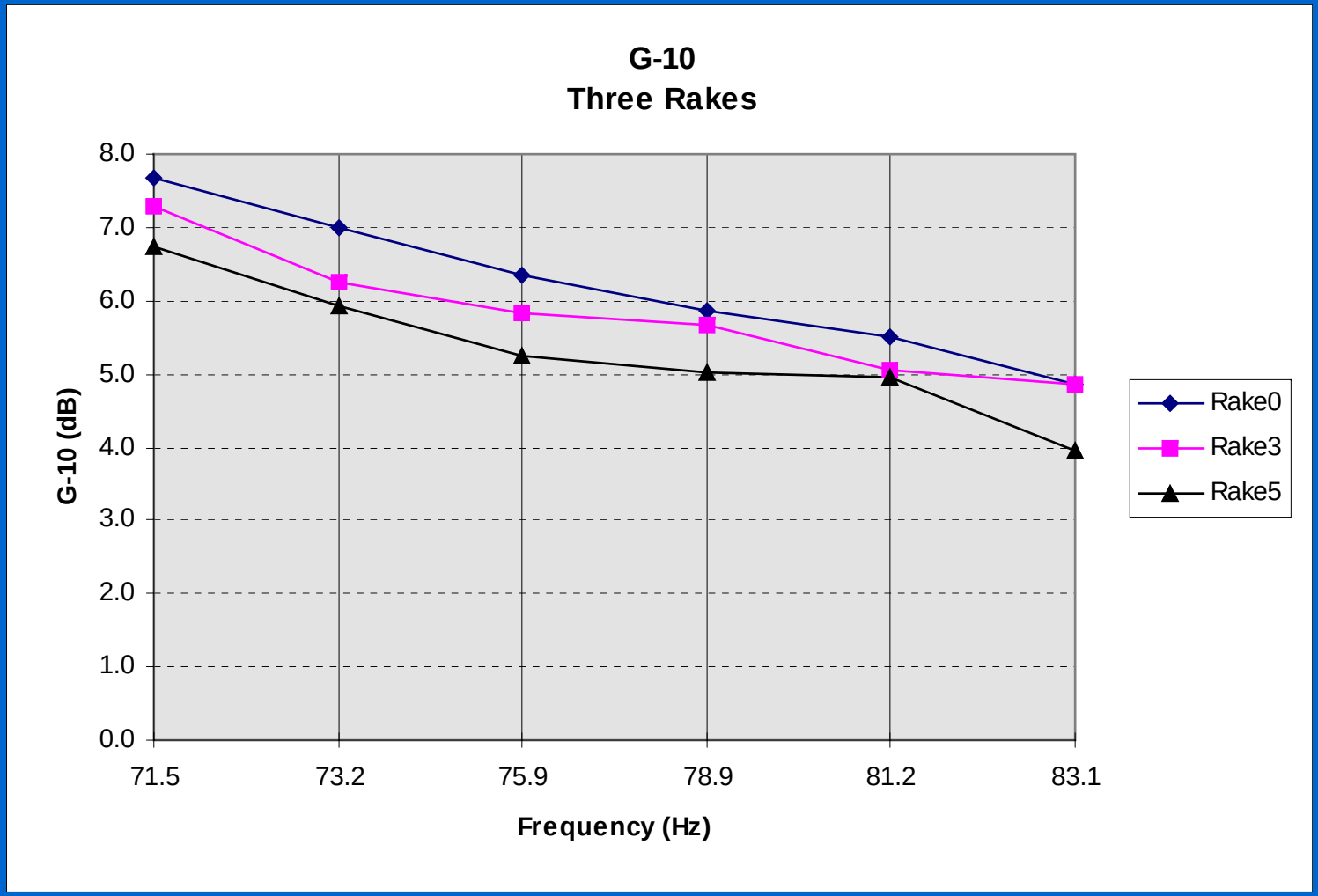




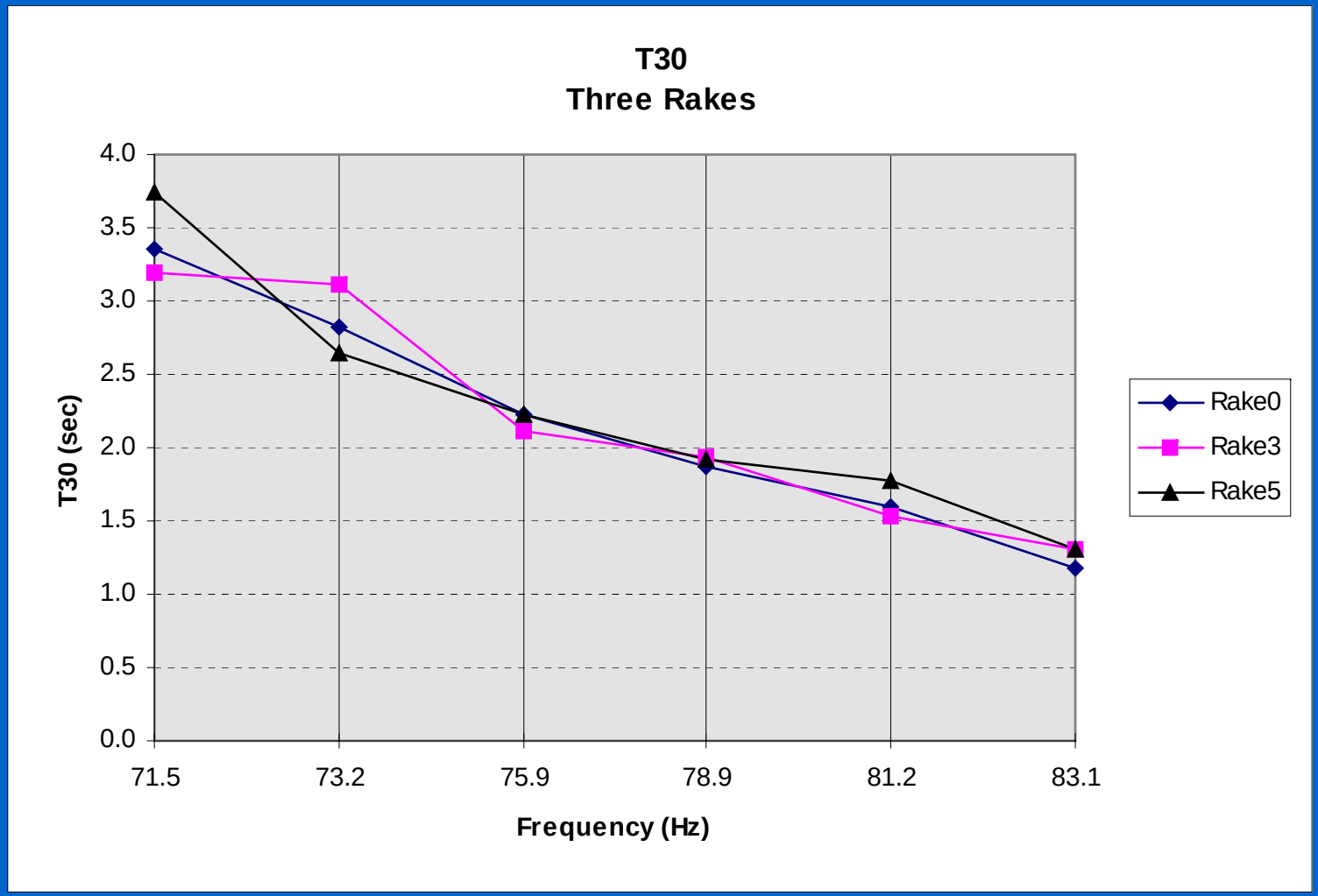
Room	Floor slope
Rake0	0
Rake3	5.7 deg
Rake5	9.5 deg

L = 30 m, W = 20 m H = 10 m +
Floor slope increased in 2 steps.
Ceiling height adjusted for equal volume.
Audience absorption on floor.
Plaster walls with moderate diffusion.

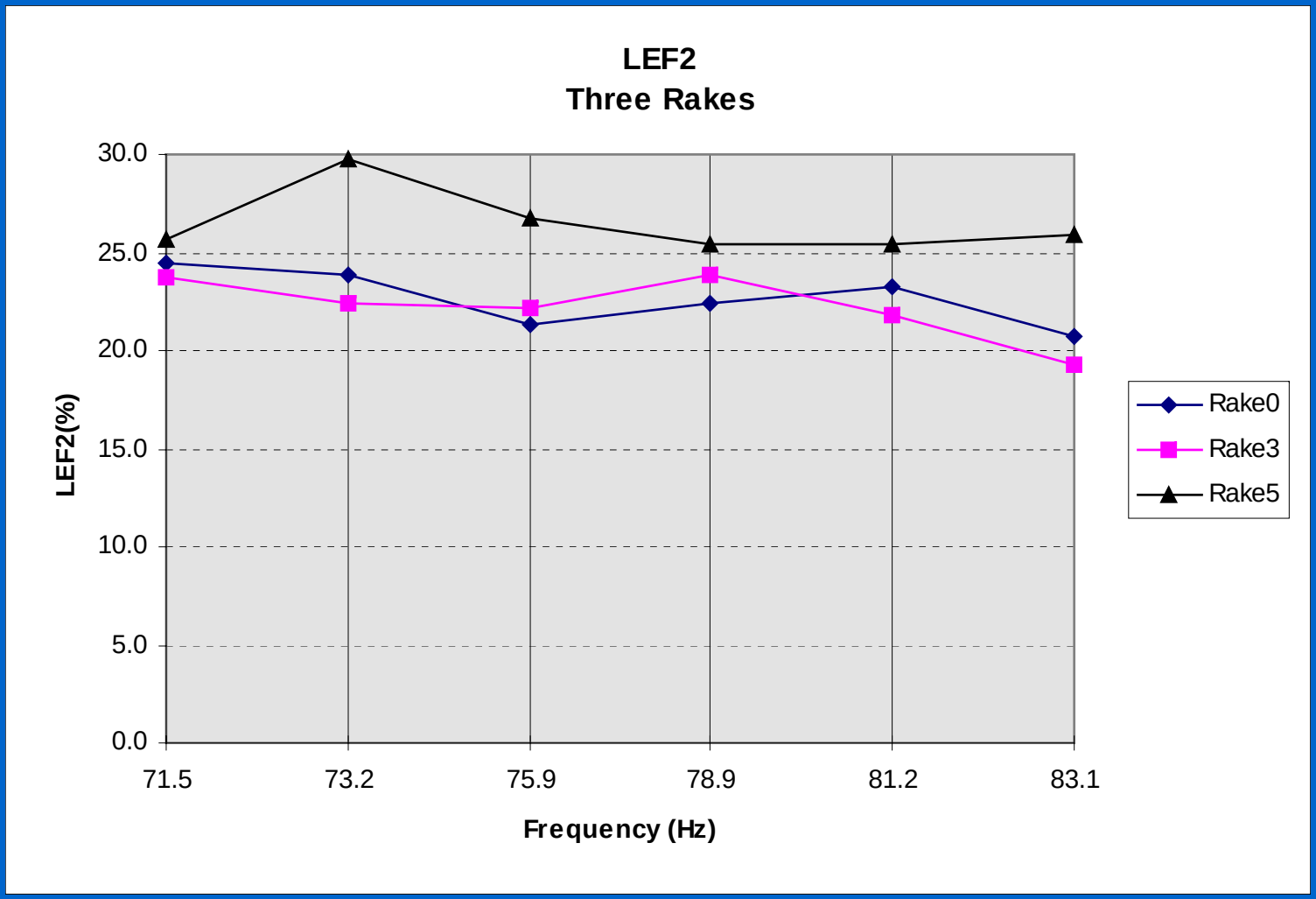
G-10: Three rakes



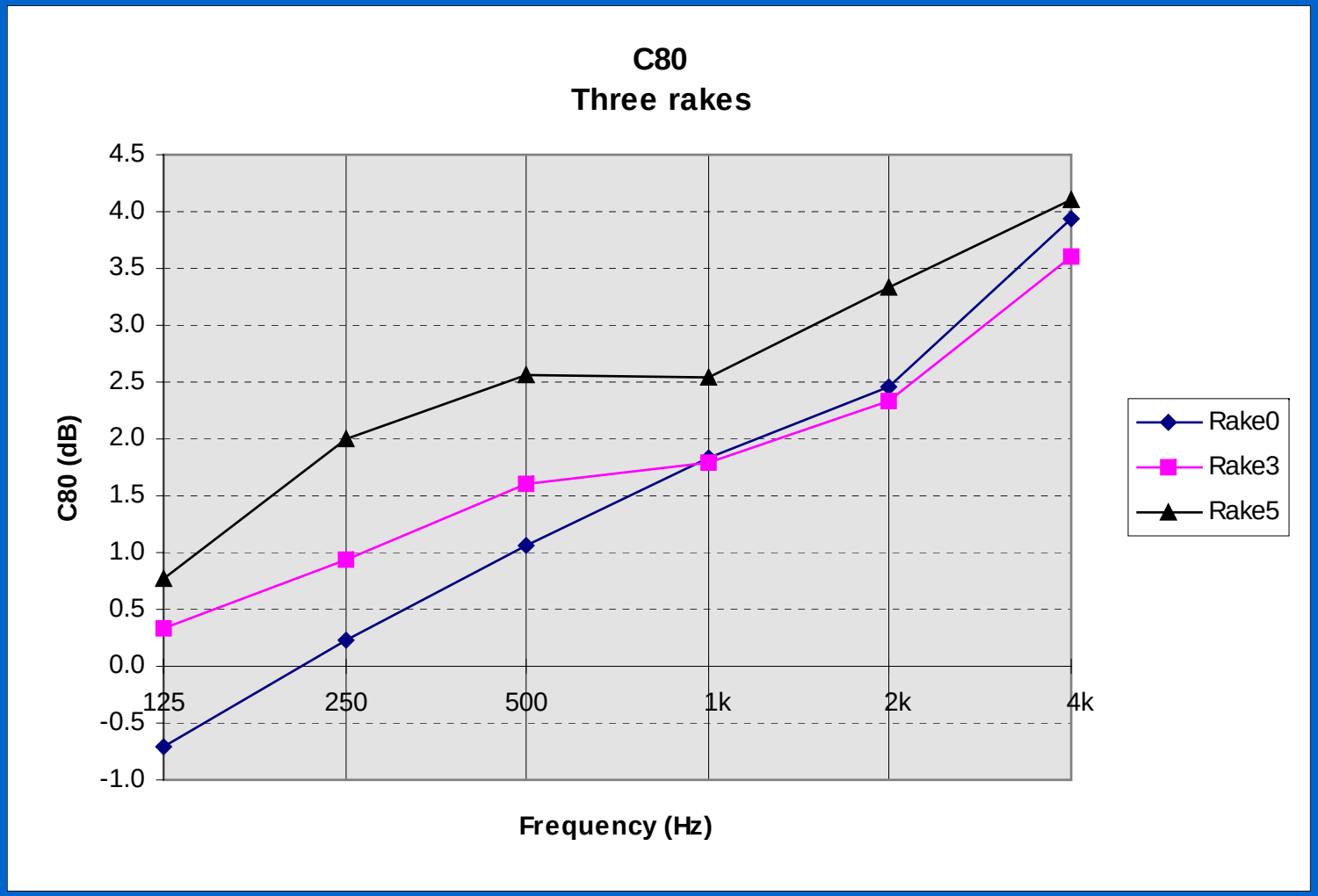
T30: Three Rakes



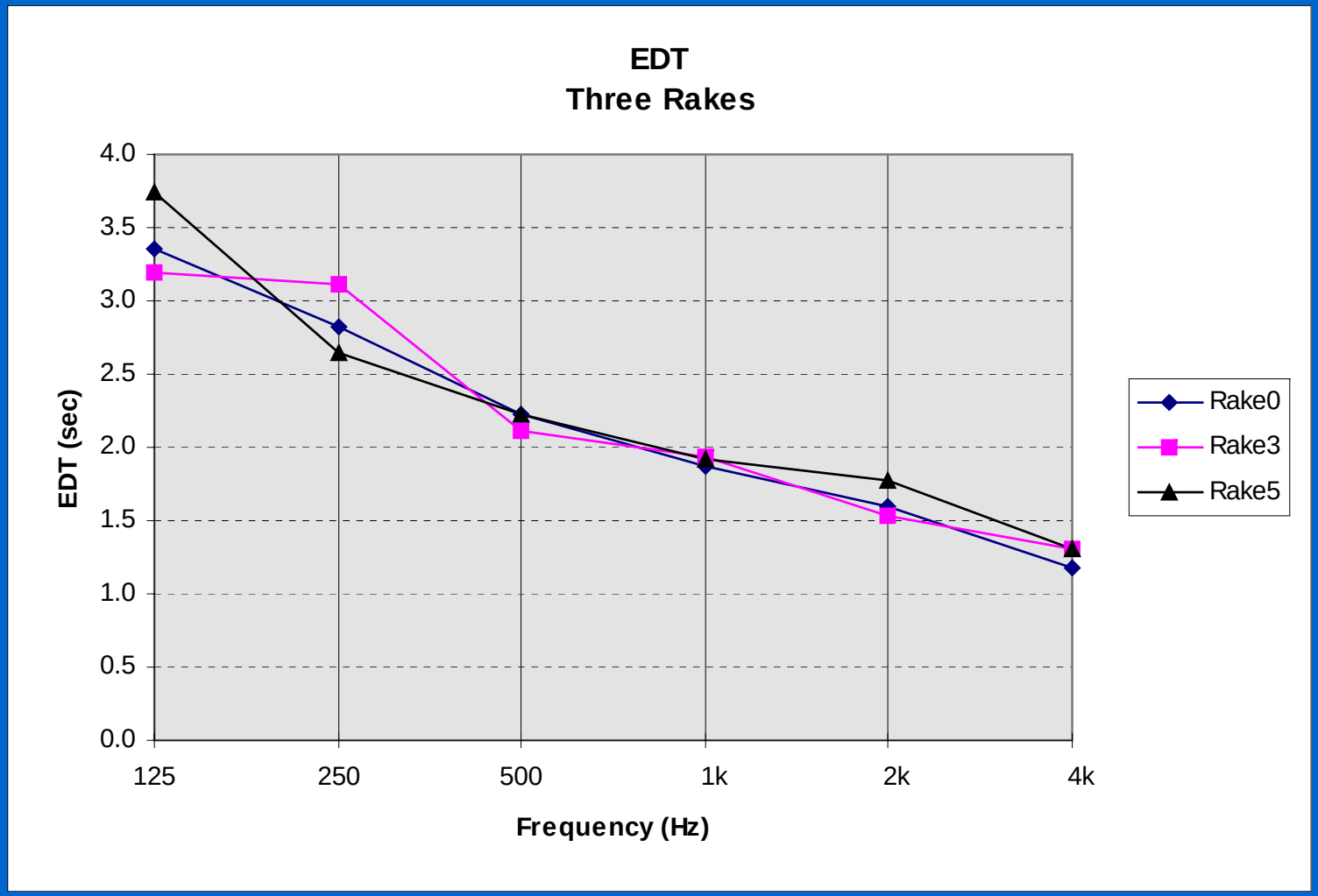
LEF2: Three Rakes



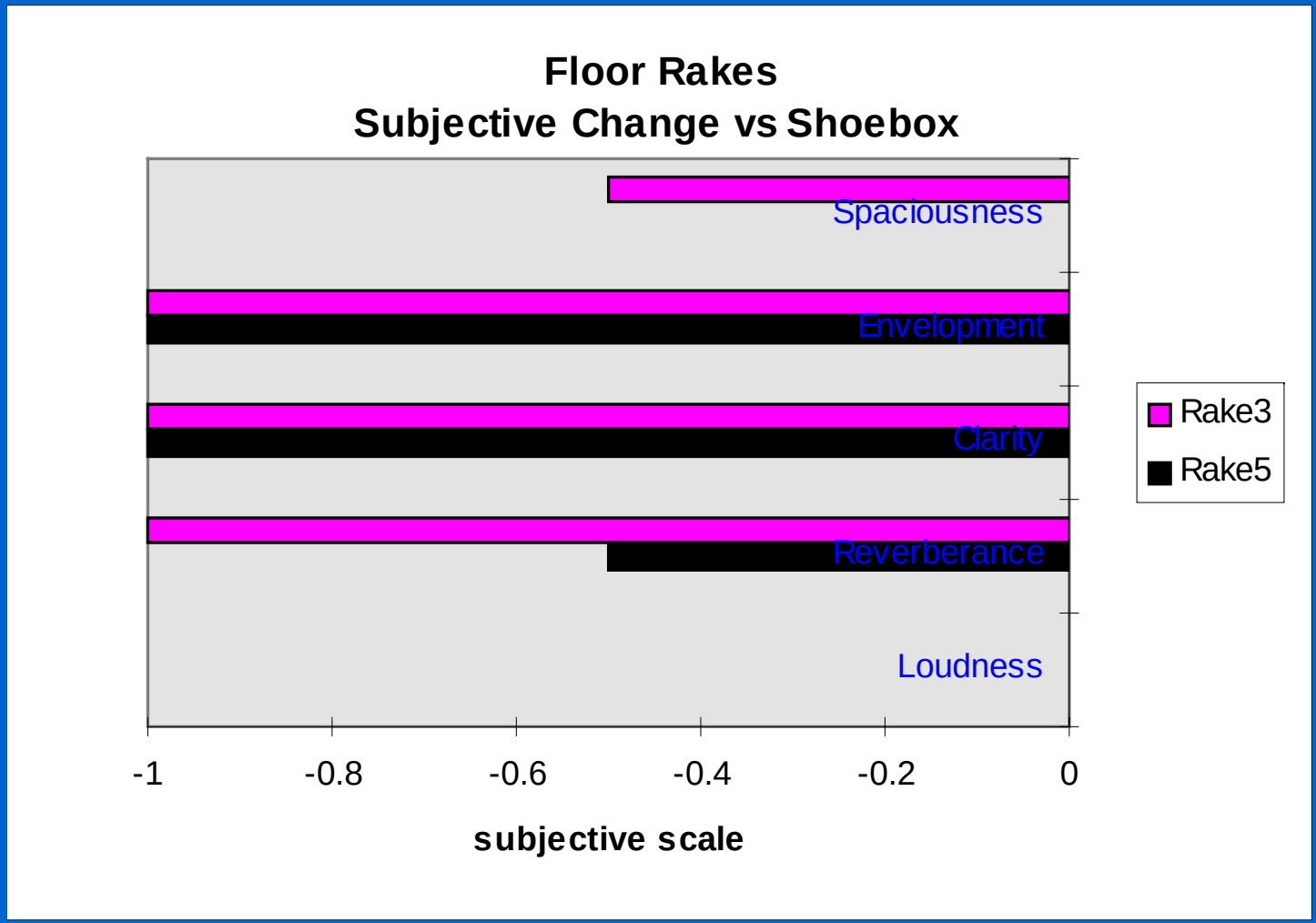
C80: Three Rakes



EDT: Three Rakes

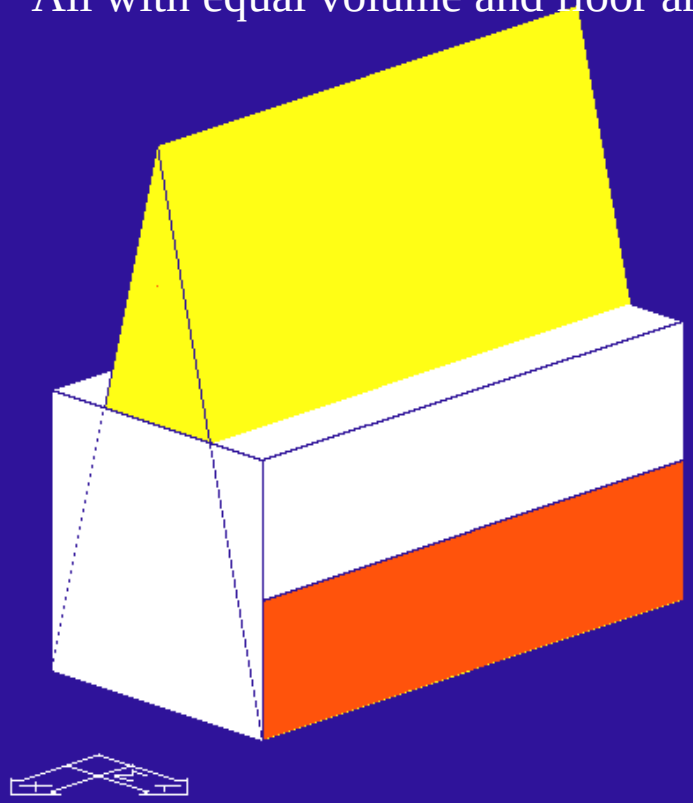


Floor Rakes: Subjective vs Shoebox

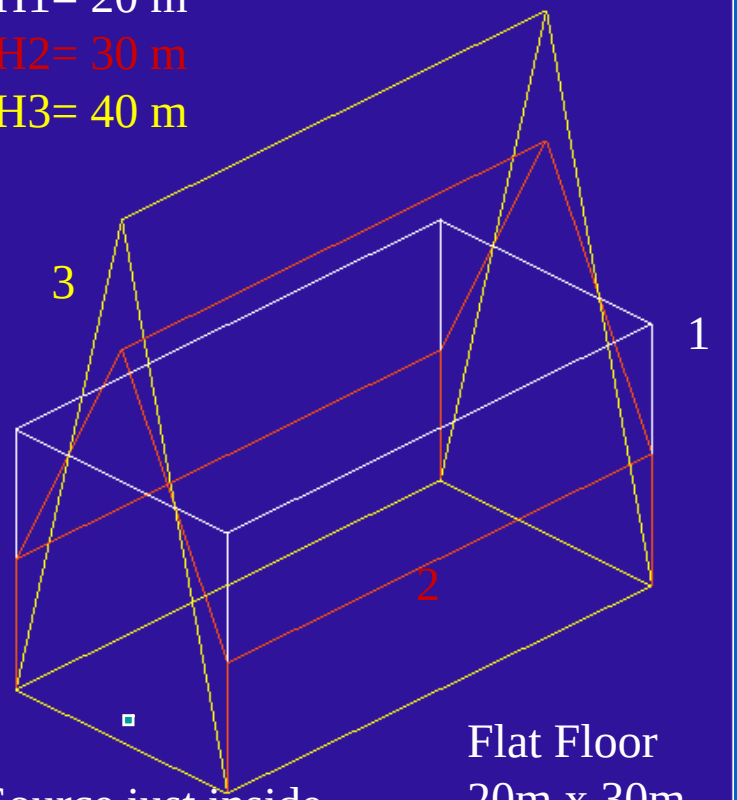


Ceiling Pitch Variation

Shoebox plus 2 celing pitches
All with equal volume and floor area



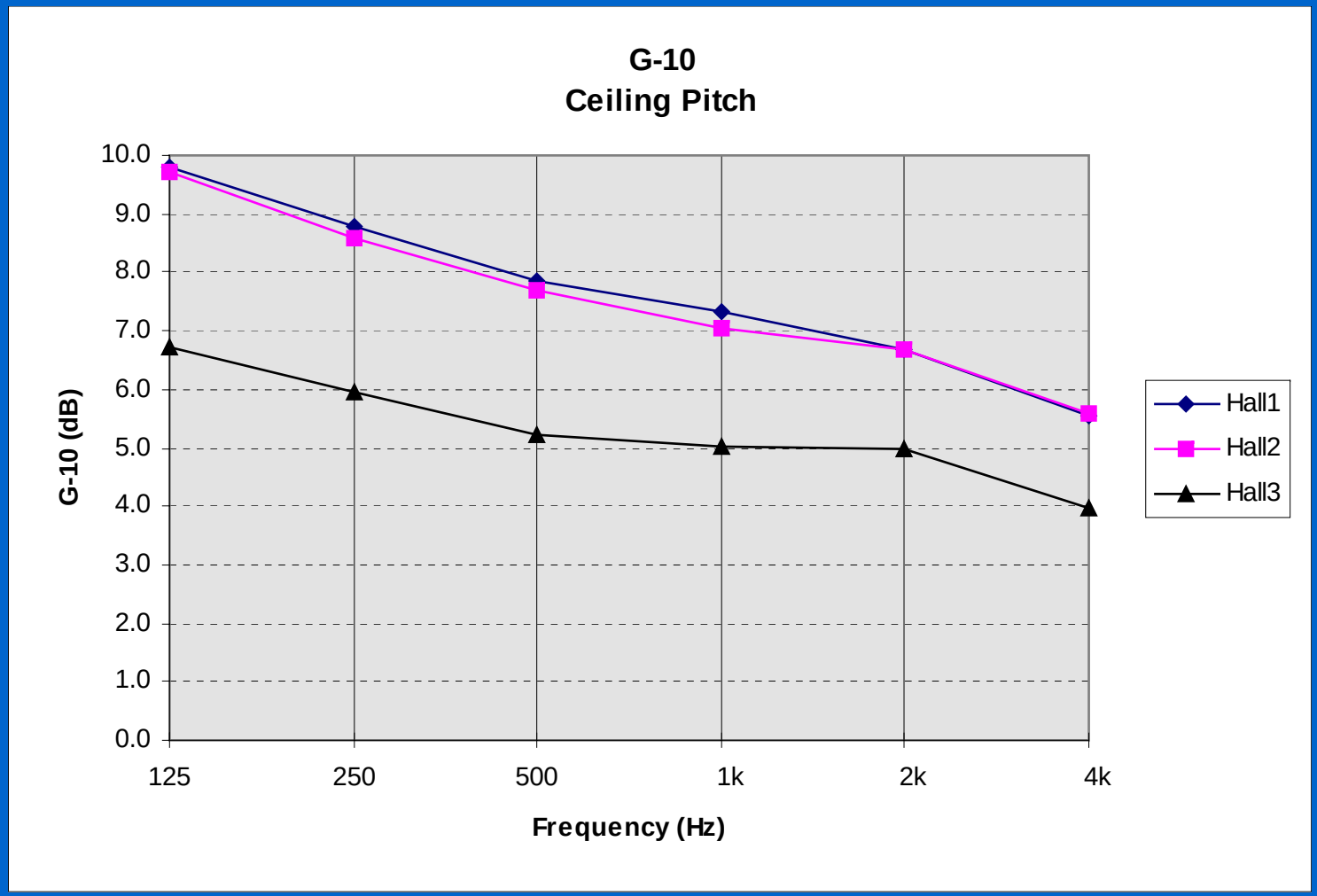
H1= 20 m
H2= 30 m
H3= 40 m



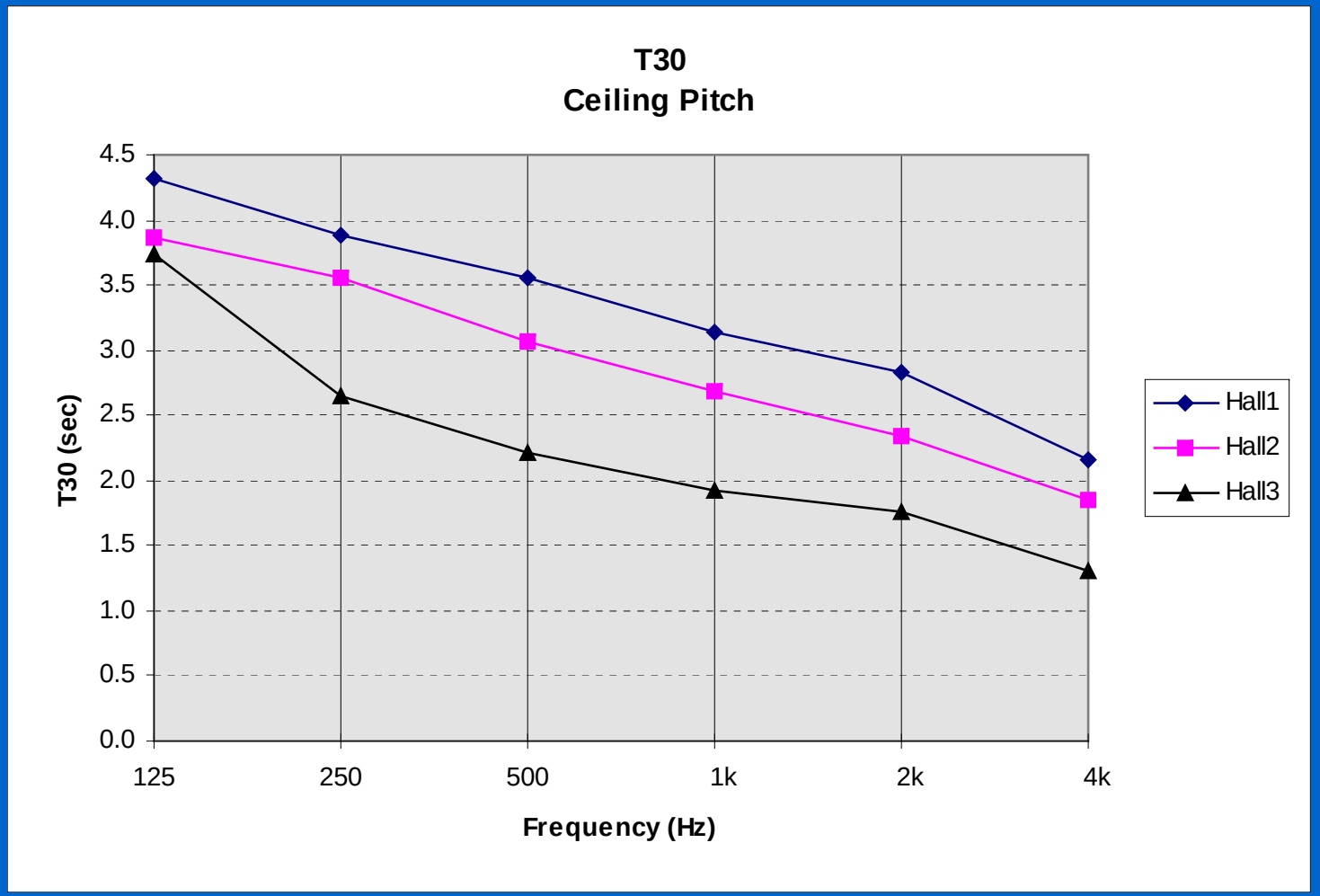
Source just inside one end

Flat Floor
20m x 30m

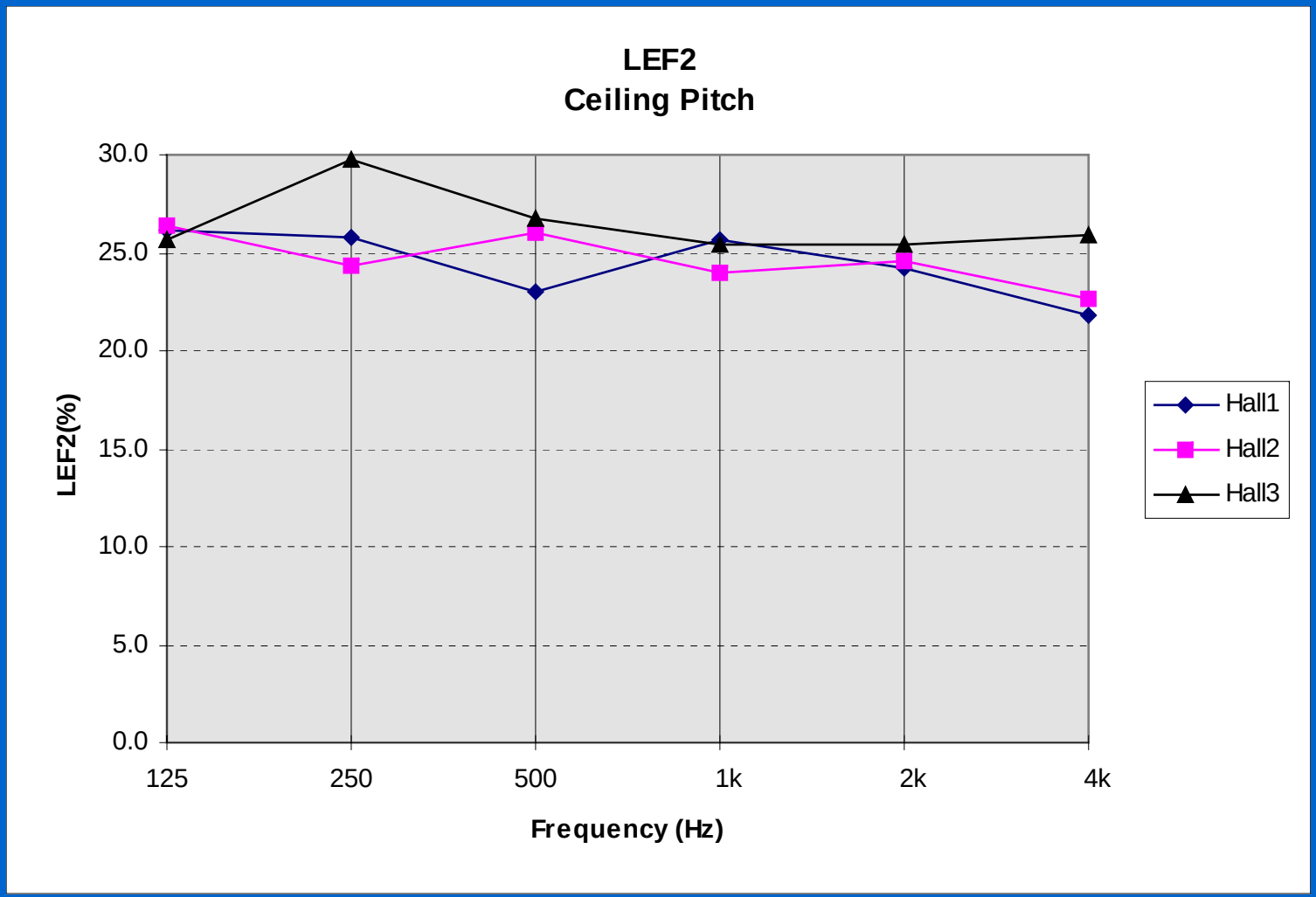
G-10: Ceiling Pitch



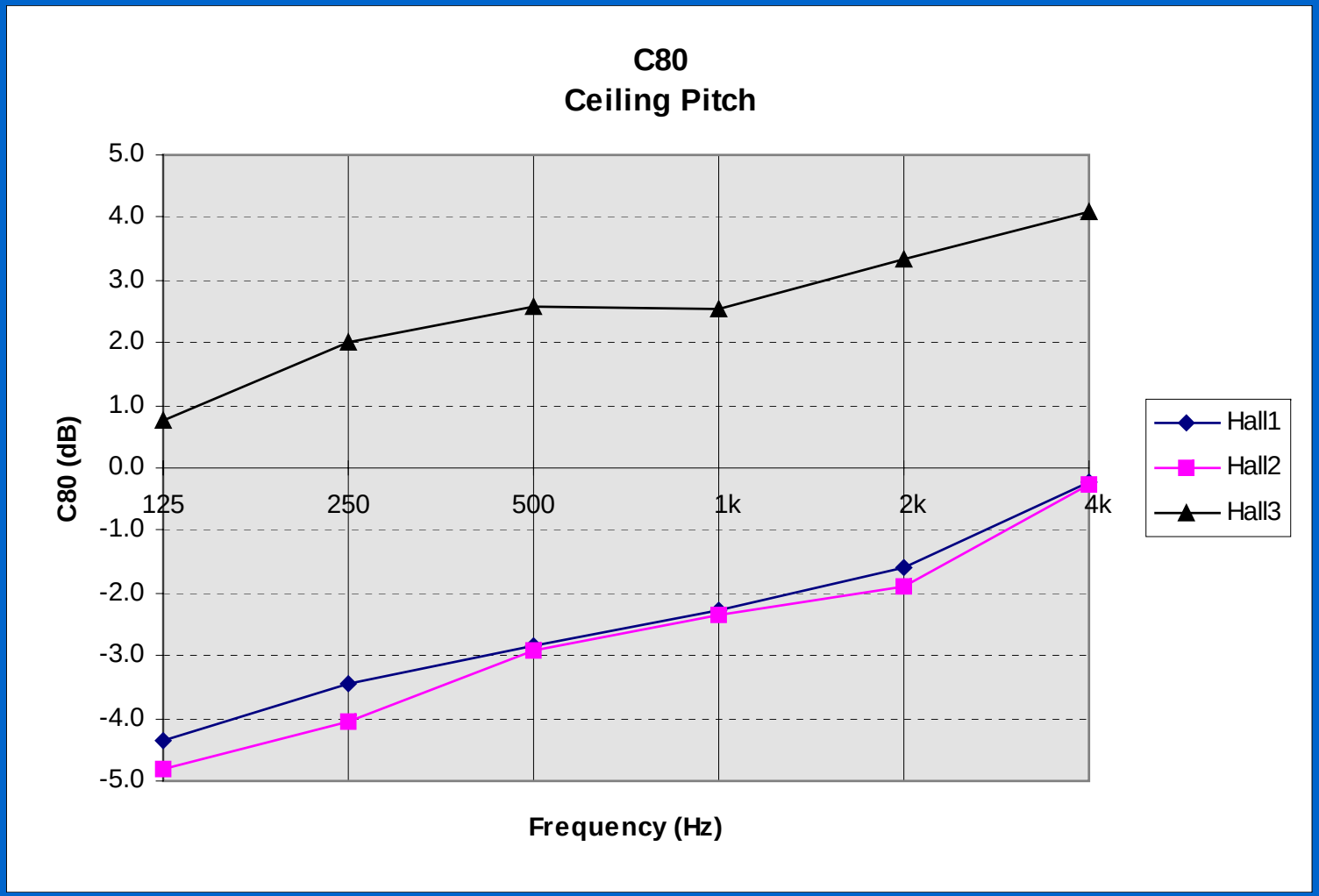
T30: Ceiling Pitch



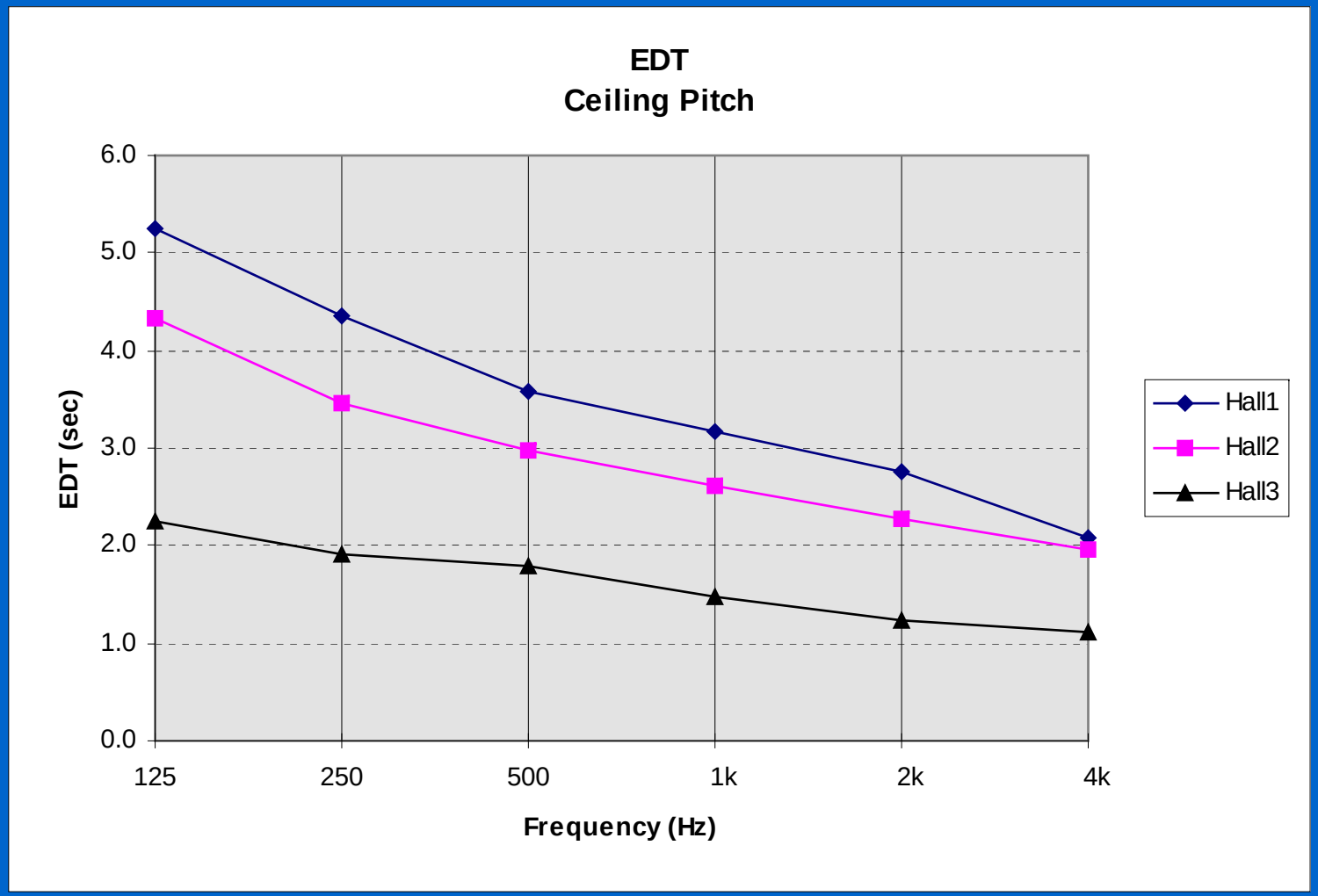
LEF2: Ceiling Pitch



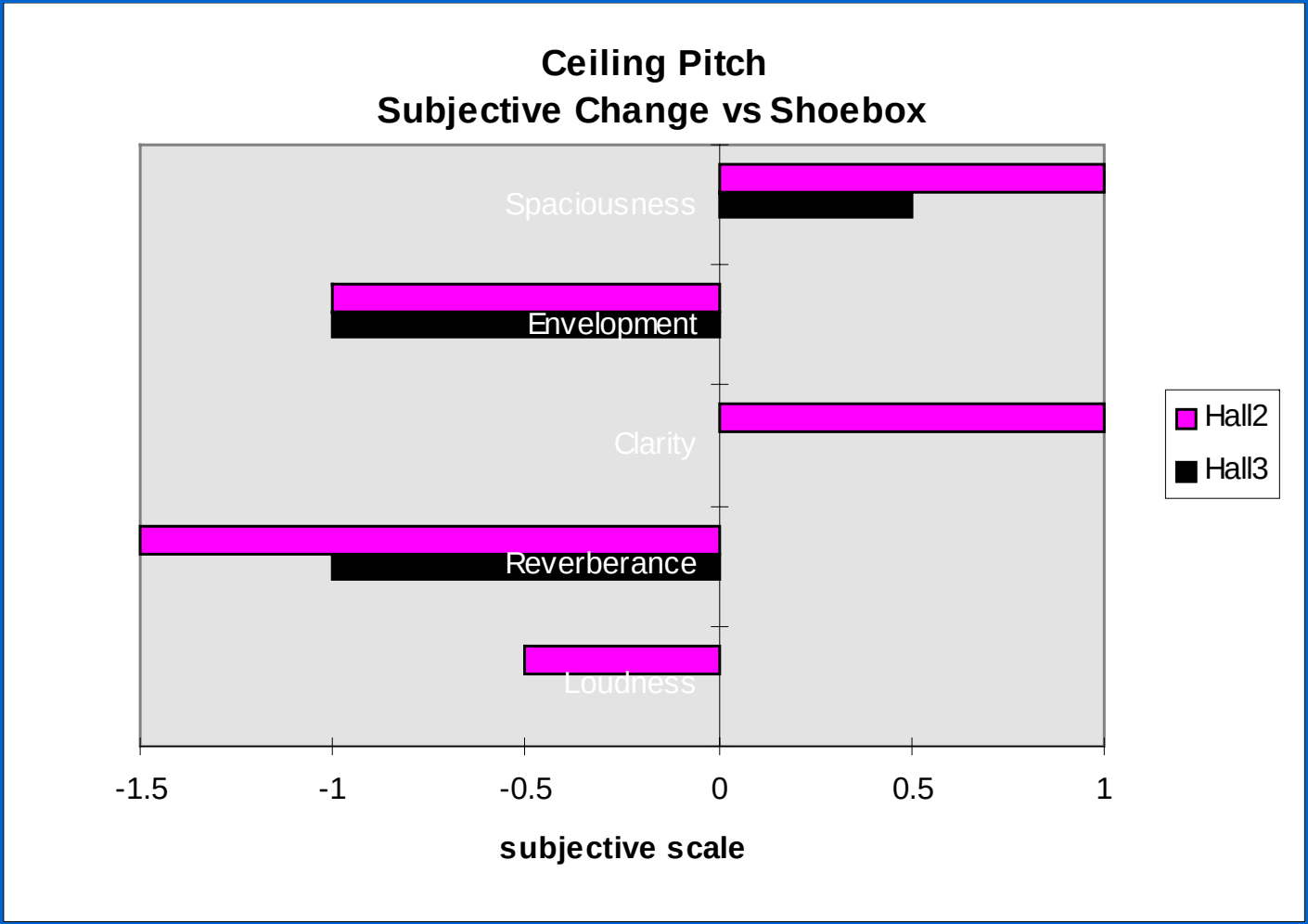
C80: Ceiling Pitch



EDT: Ceiling Pitch

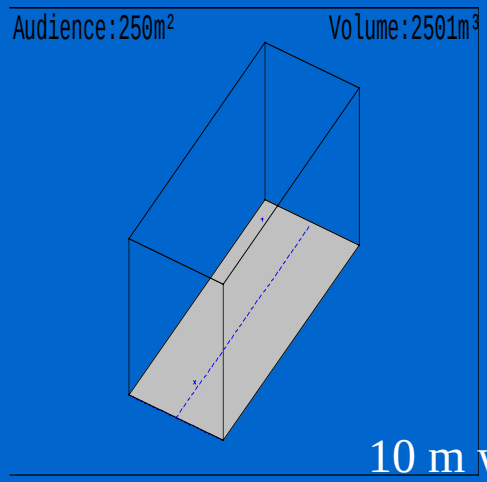


Ceilng Pitch: Subjective Relationships



Shoebox comparisons

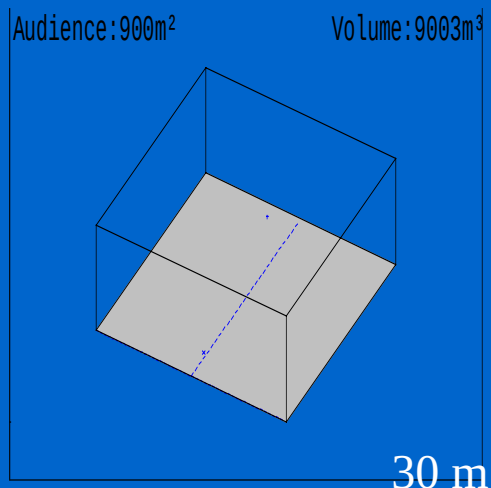
Length = constant 30 m
Height = constant 10m
Varied width (10, 20, 30, 40m), surface diffusion



10 m wide

10% Diffusion (freq indep)

50% Diffusion



30 m wide

10% D

50% D

Conclusions

- Reverberation efficiency (reverberance for a given volume) for rectangular rooms is greater than these other shapes
- For these simple shapes we can demonstrate trends with models that correspond to experience in real world