The Acoustic Evaluation of Frequency Balanced Words at the Eardrum and their use in Fitting Hearing Aids.

The Hearing and Speech Foundation
A presentation by John Berry, Bernadette Kos
Funded by Alan and Judy Boeckmann and the Fluor Foundation

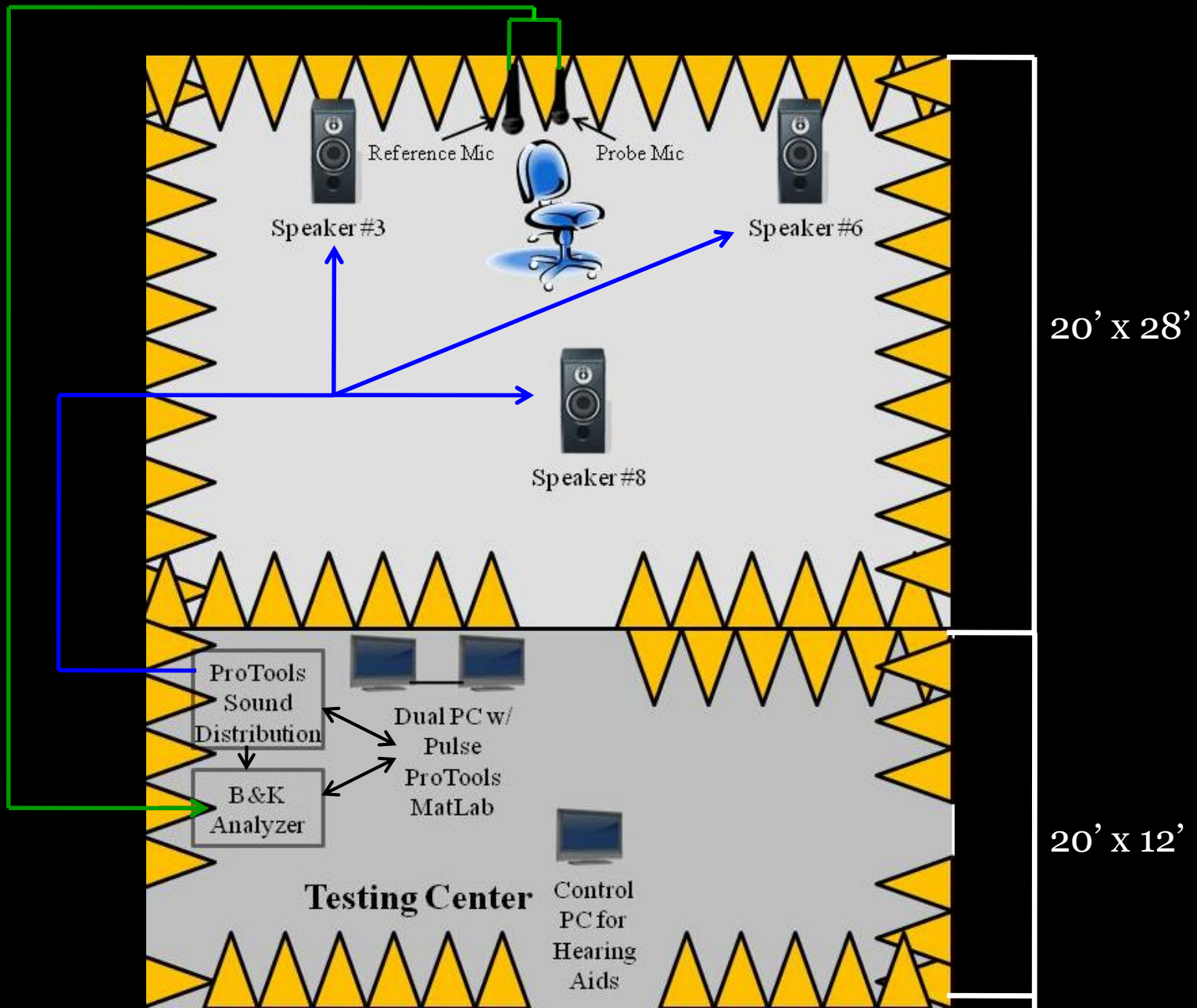
Presentation Outline

- Room set-up and calibration of system
- Comparison of reference and probe microphones for pure tone and speech in free field
- Using speech as a criteria for fitting hearing aids
- Procedure for collecting data
- Rational for Bessel's word list
- Case studies

Section I

Instrumentation Used in the Anechoic Chamber

HSF's Anechoic Chamber



Wedges designed for 125 Hz cutoff

PC - Controlled Testing Equipment

- Bruel & Kjaer 3560-C
- Precision digital signal analyzer
- A.K.A. – the “Pulse System”

PC - Controlled Testing Equipment

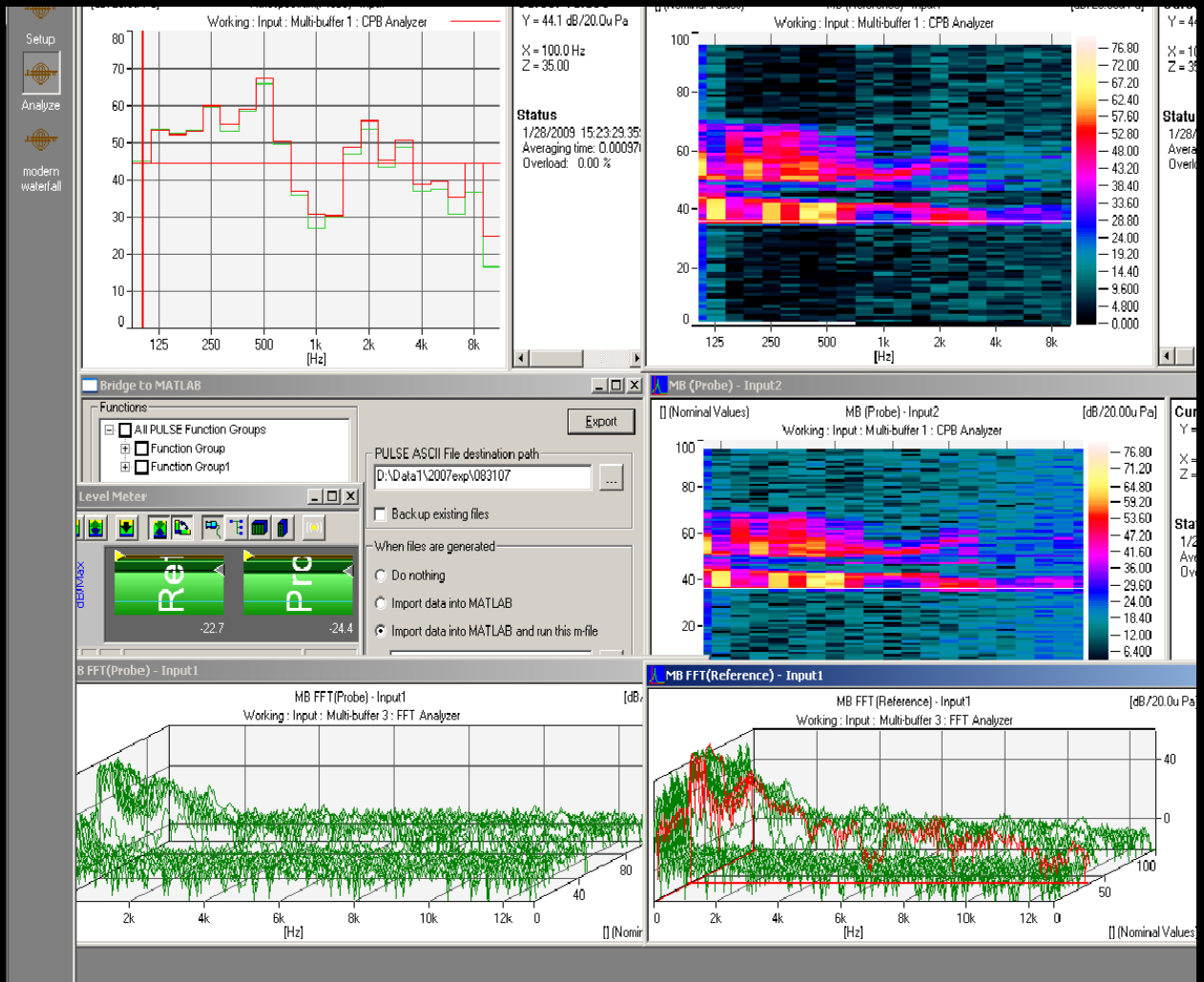
- ProTools

"Digi 002 Rack"

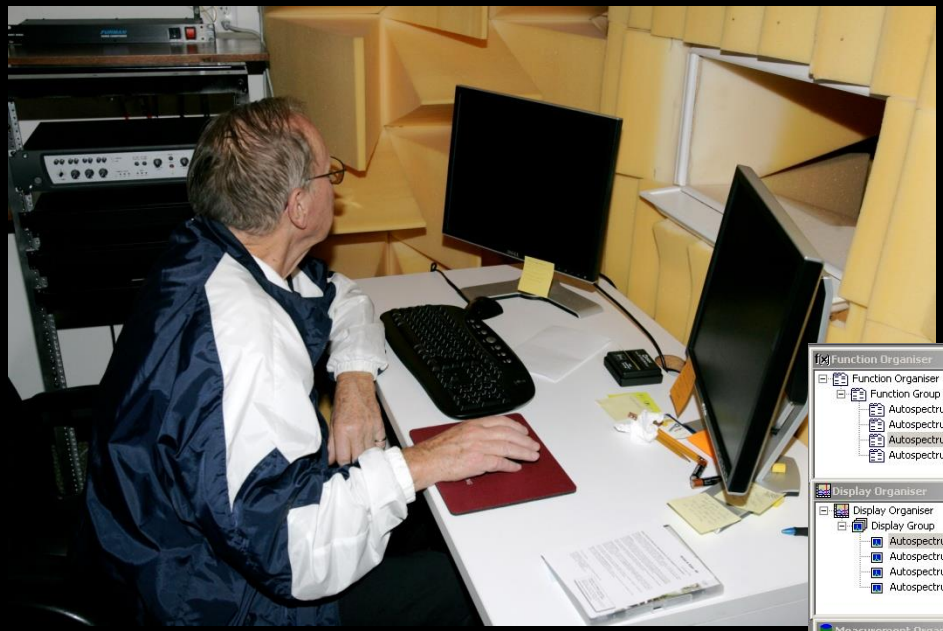
  - Professional-grade recording and playback audio system

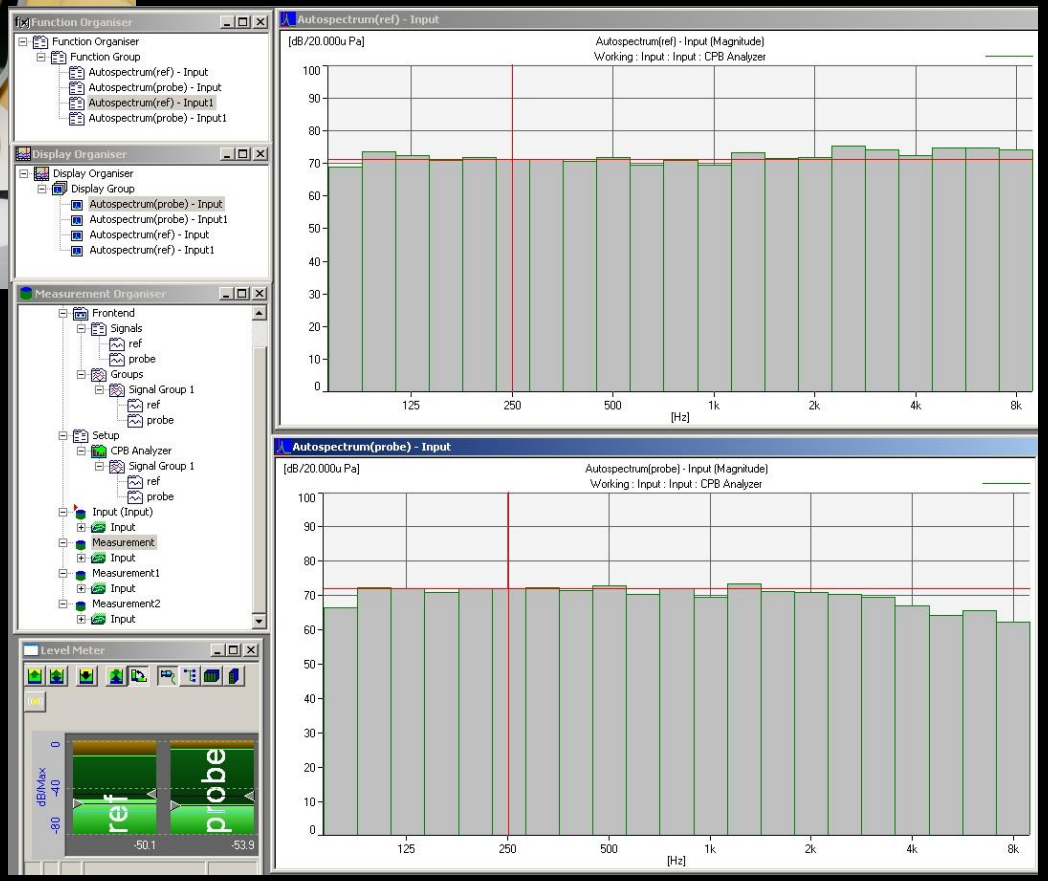
PC - Controlled Testing Equipment

- MatLab Software
  - Mathematics analysis software recognized by research and academia

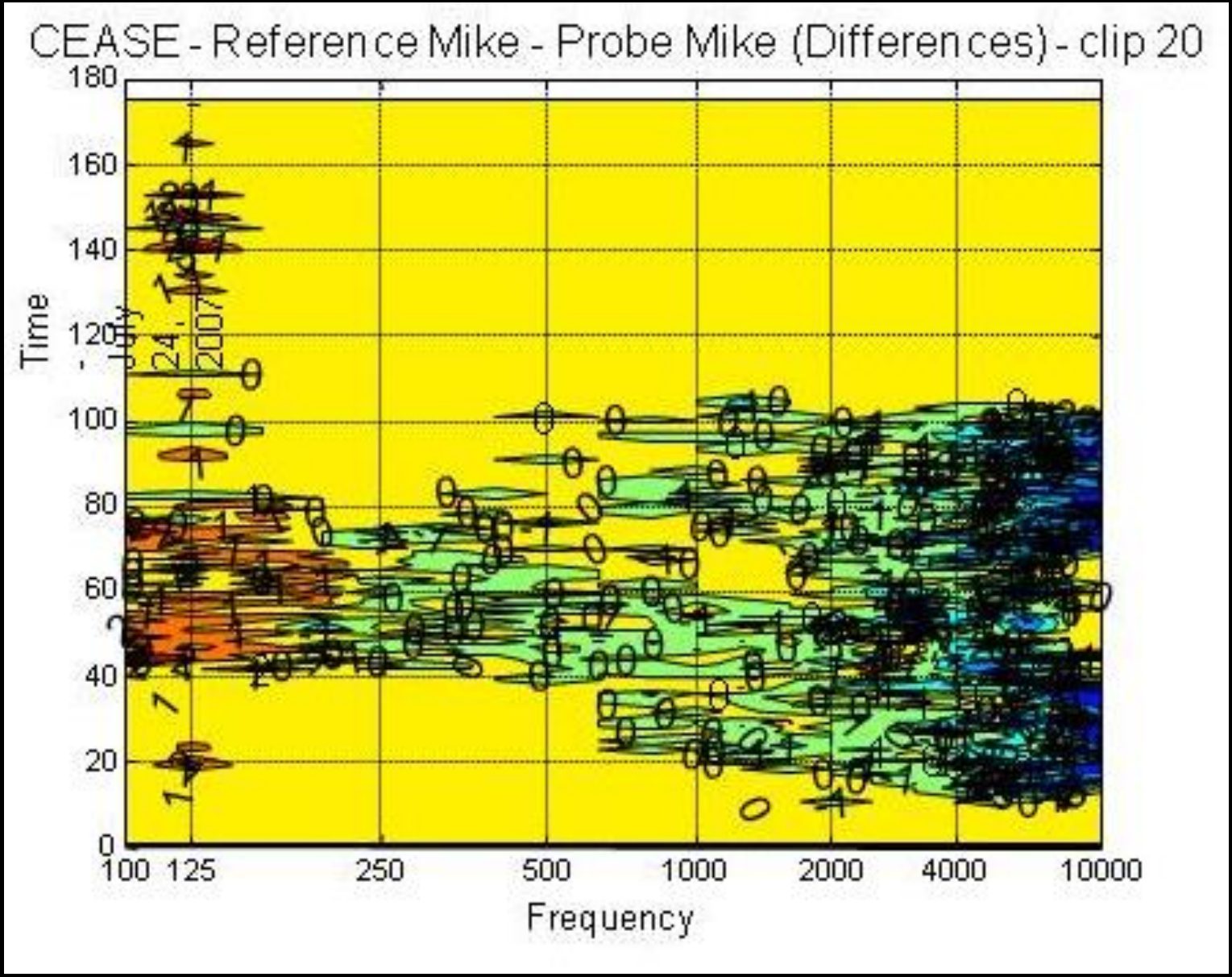


Testing and Microphone Calibration

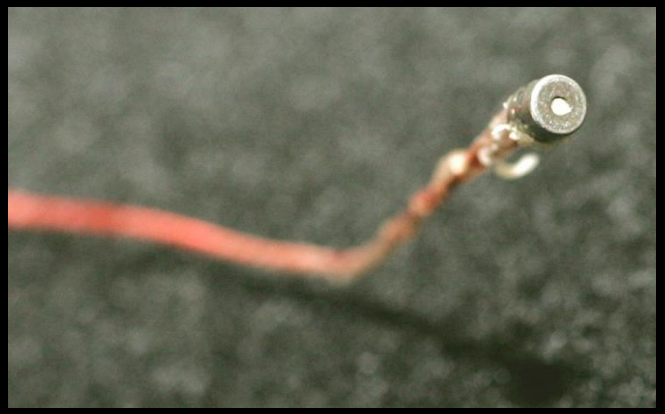




Testing and Microphone Calibration

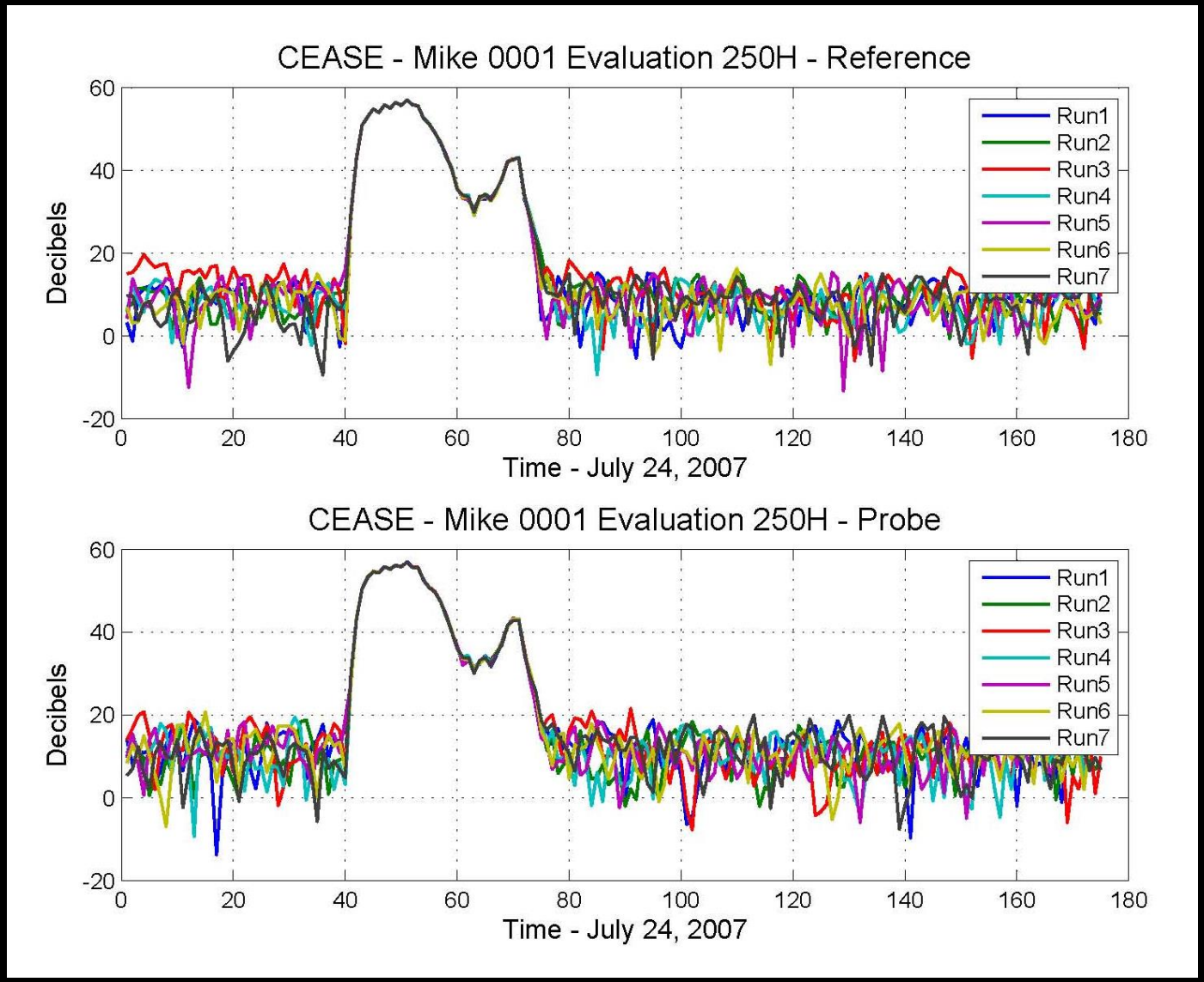


Microphone Design

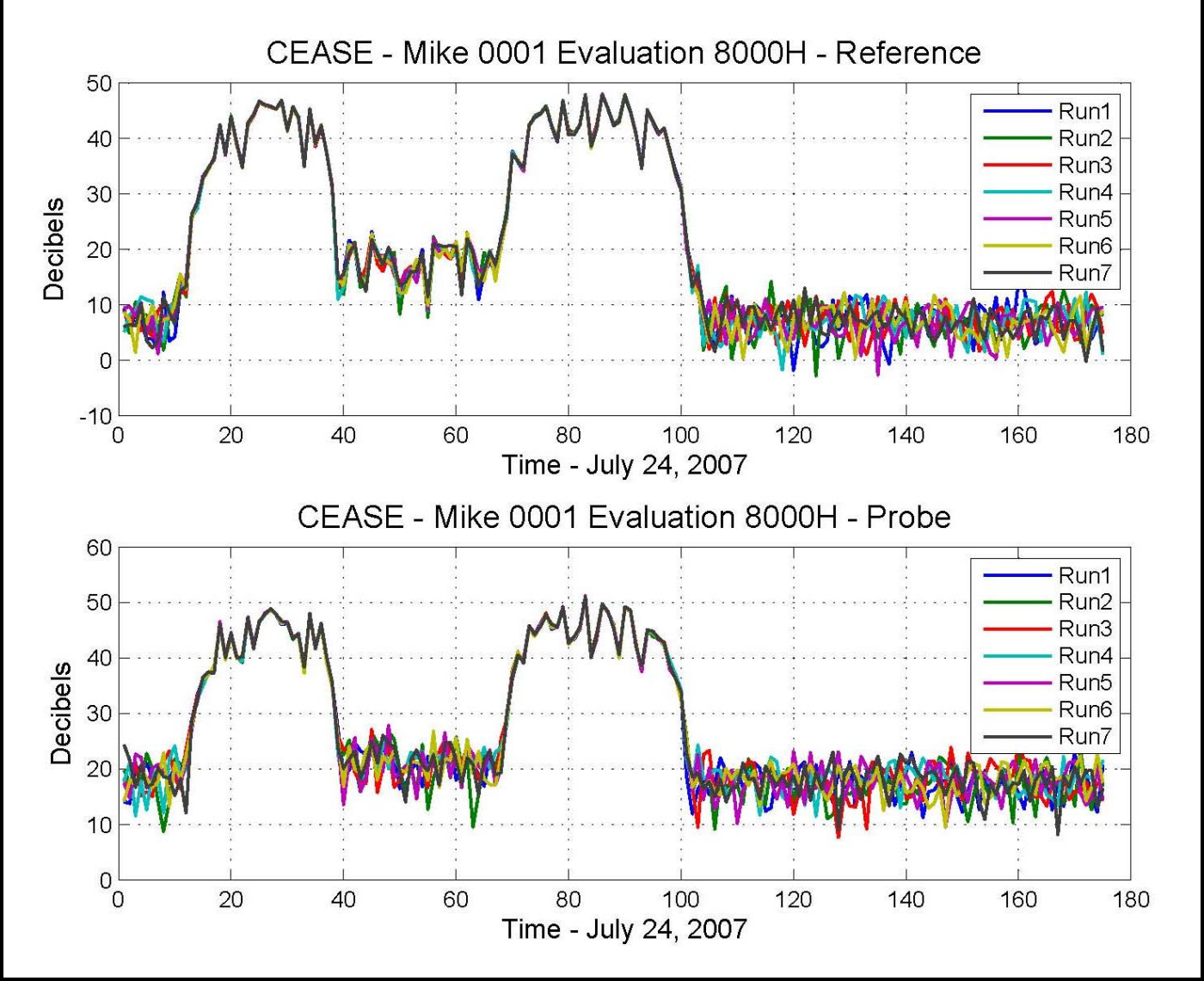


- Reference microphone
- Probe microphone
  - OEM microphone
  - attenuated to 20 dB without noise
- Testing done for noise and time delay

Microphone Design

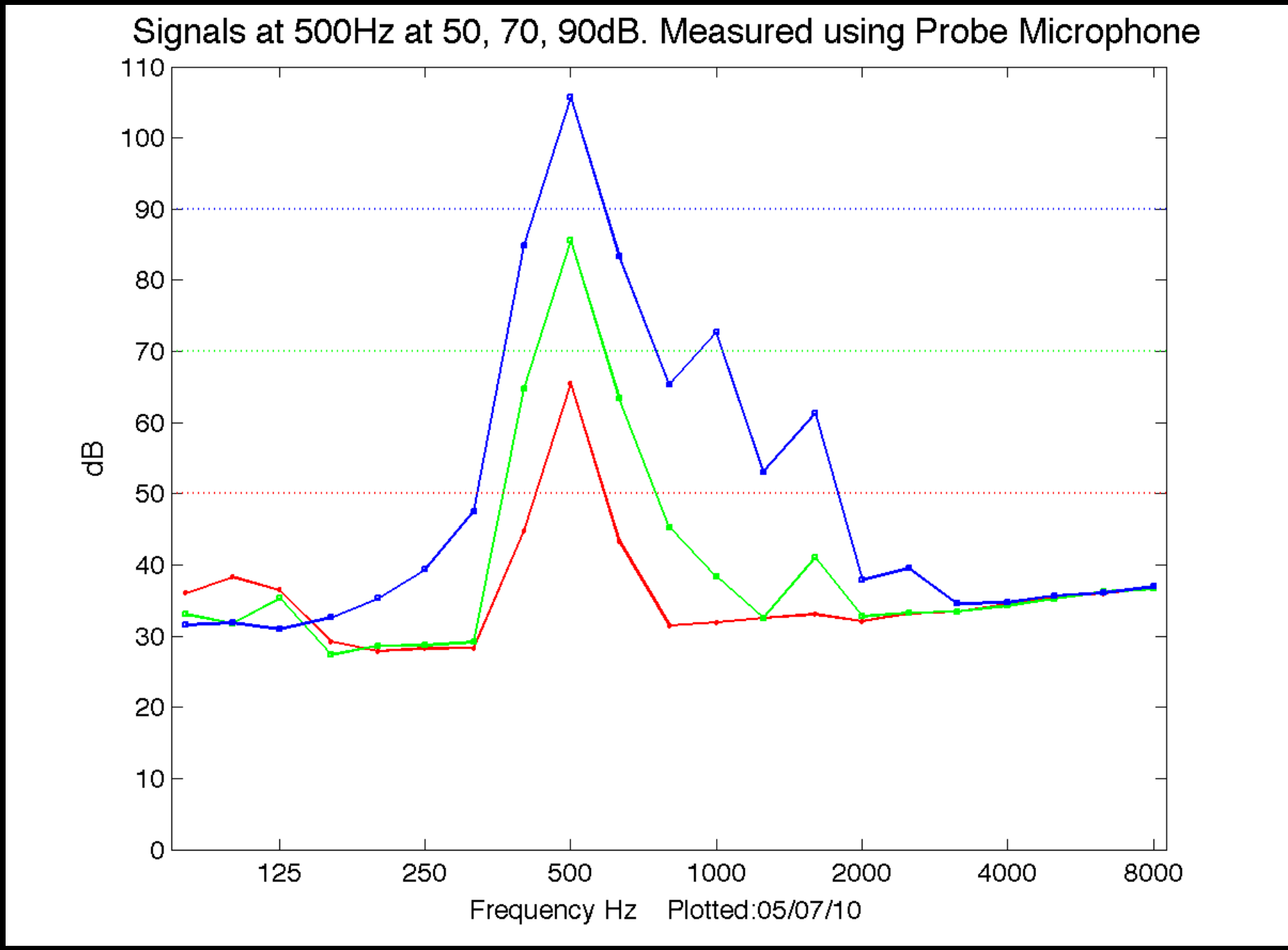


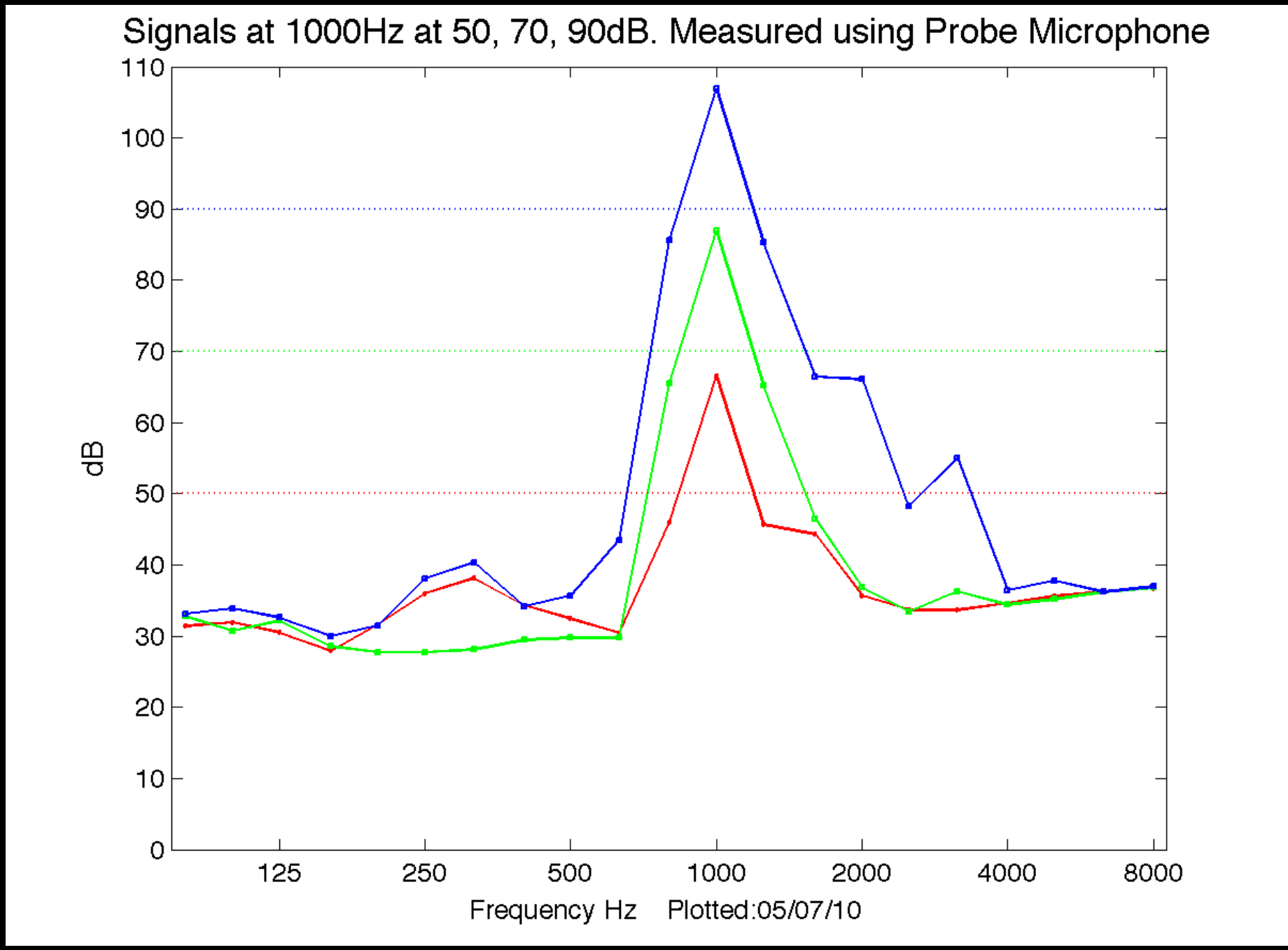
Microphone Design

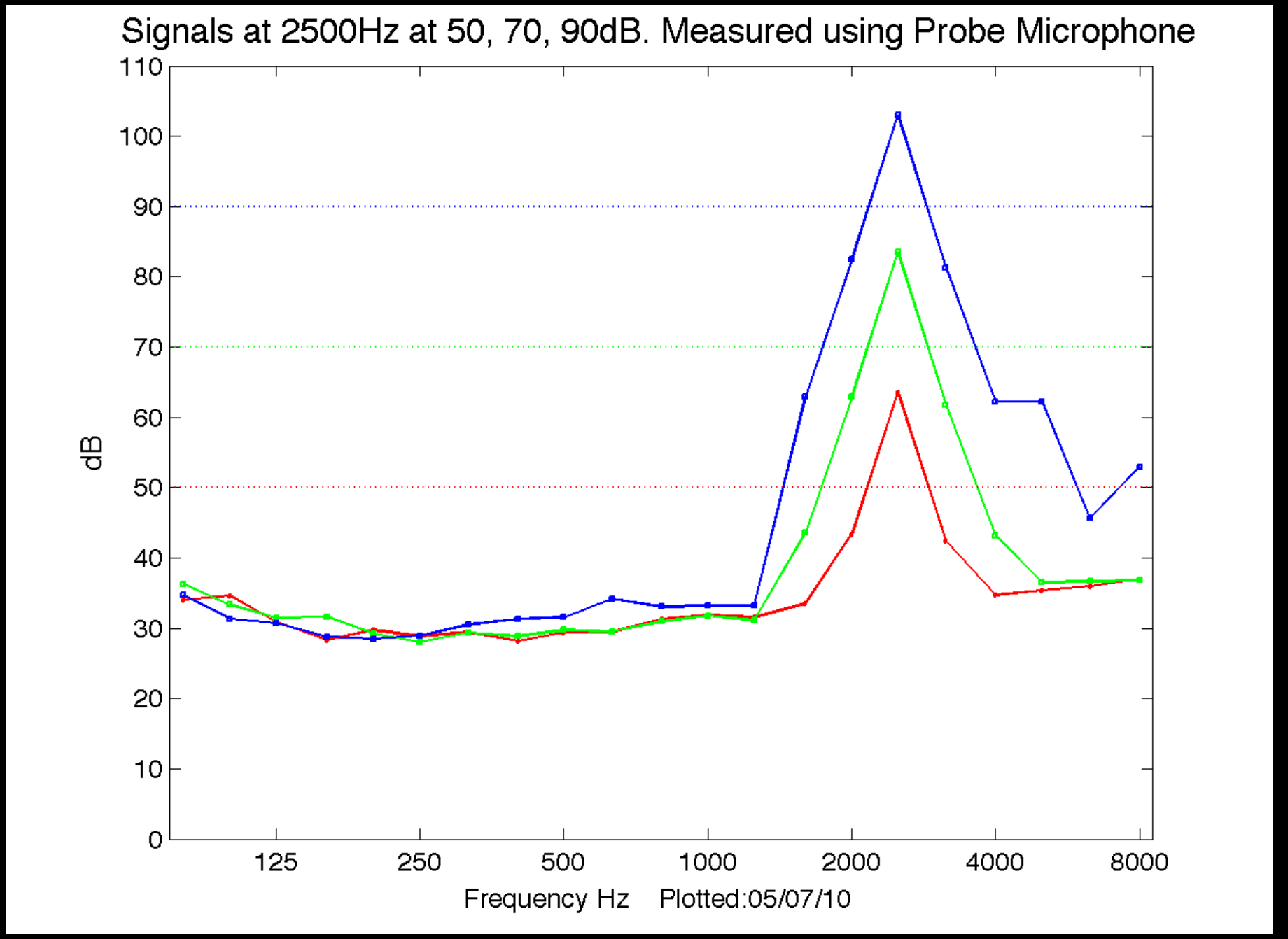


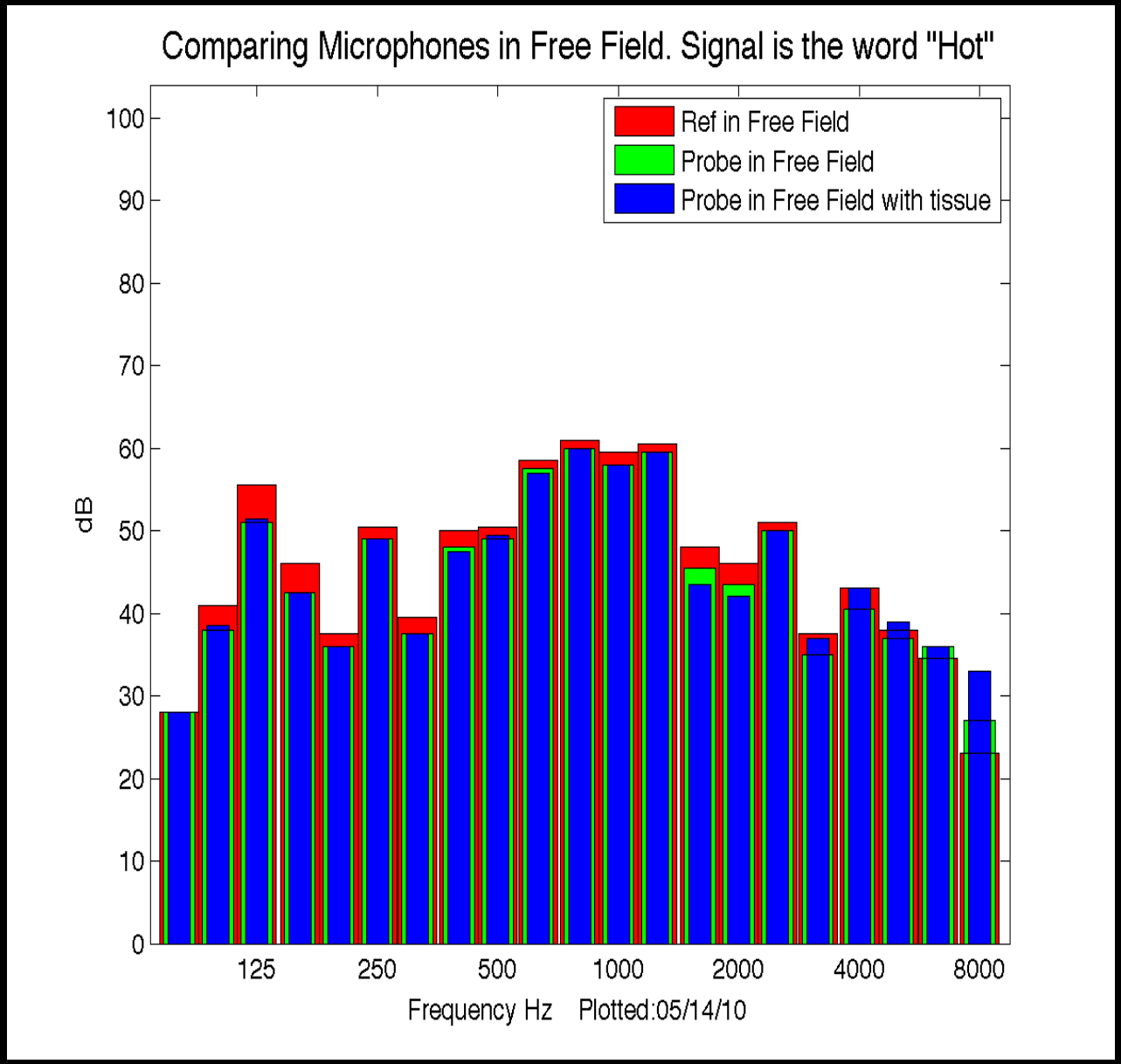
Section II

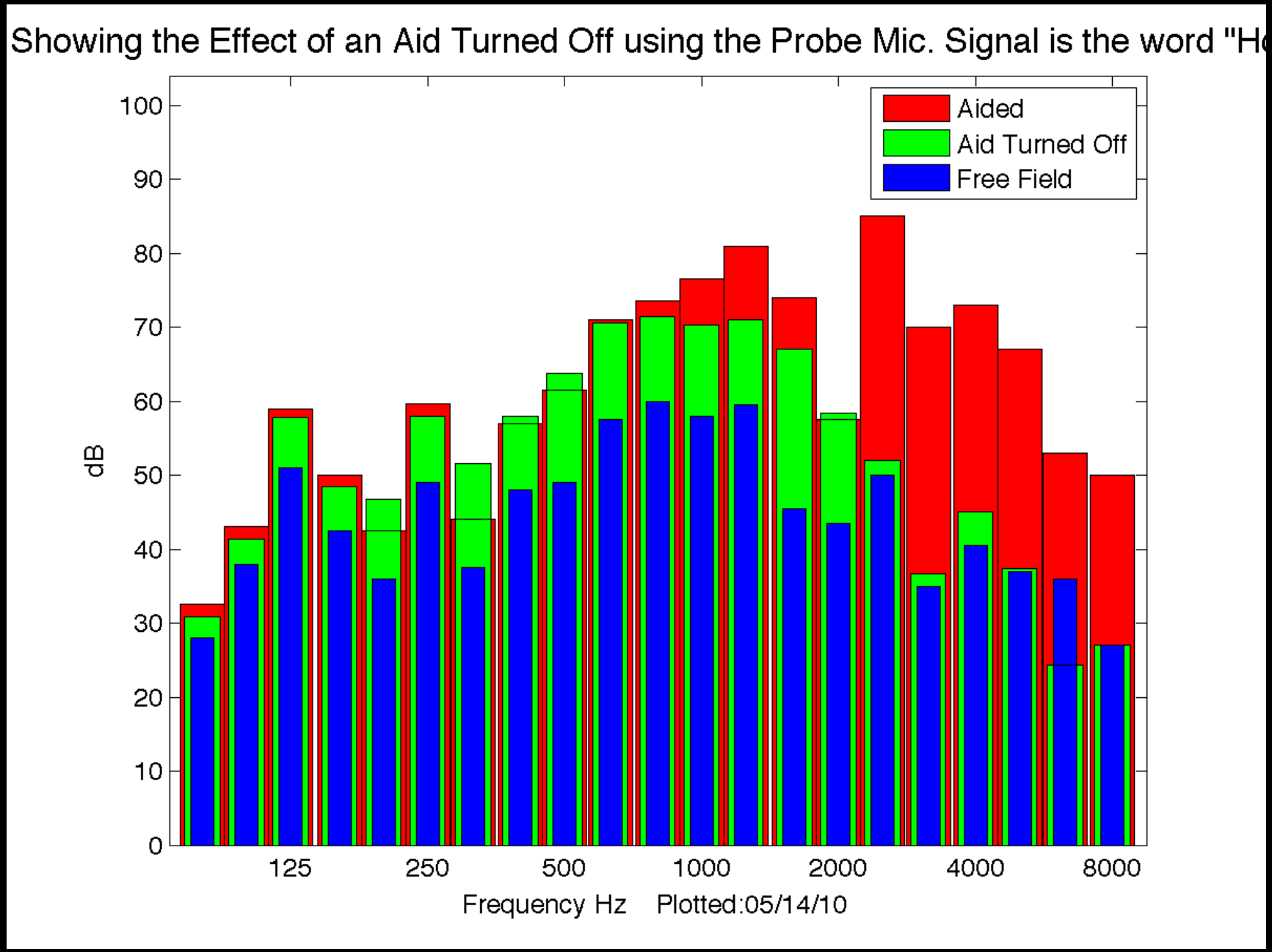
System Calibration

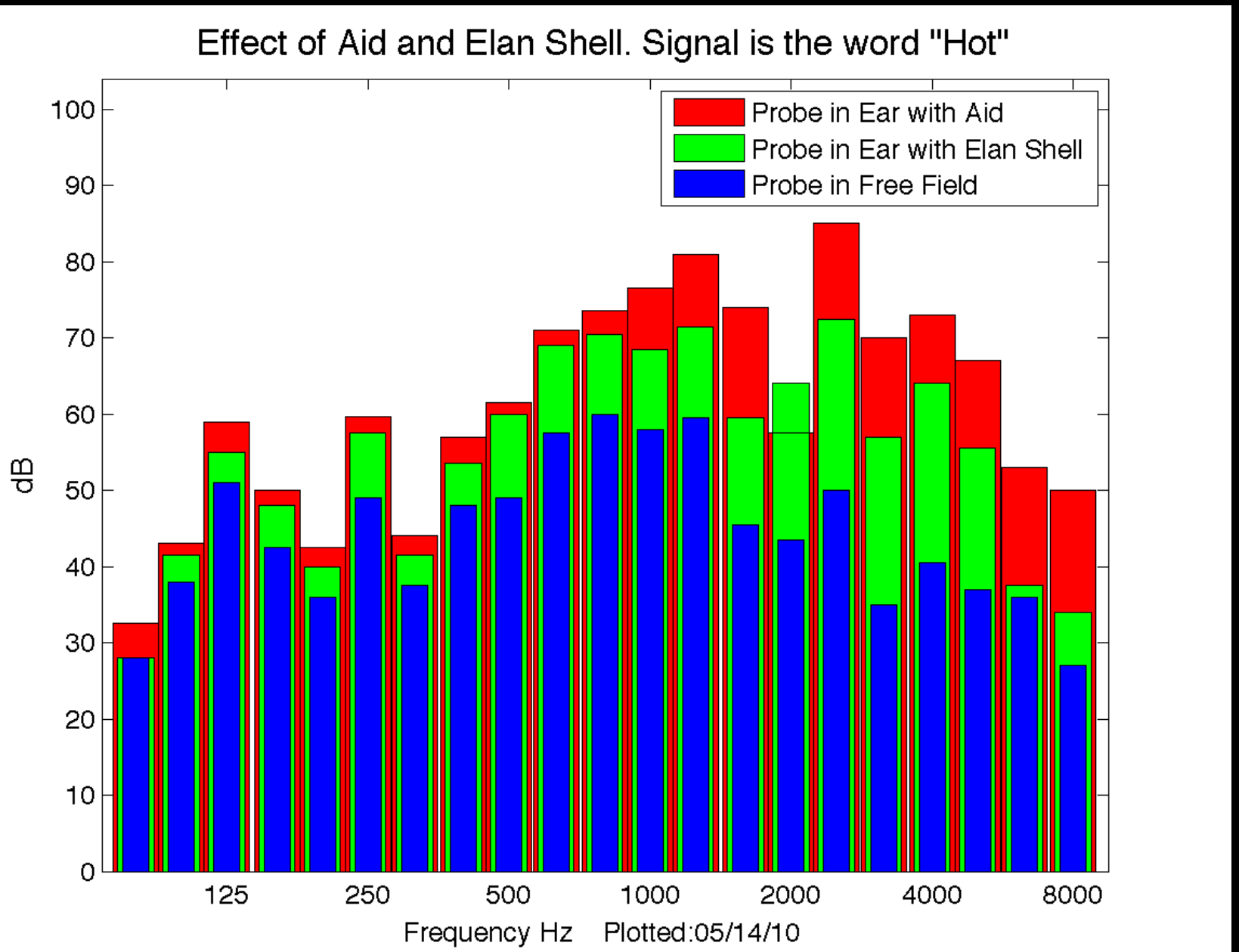

Signals at 500Hz at 50, 70, 90dB. Measured using Probe Microphone
110
100
90
80
70
60
50
40
30
20
10
0
dB
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/07/10

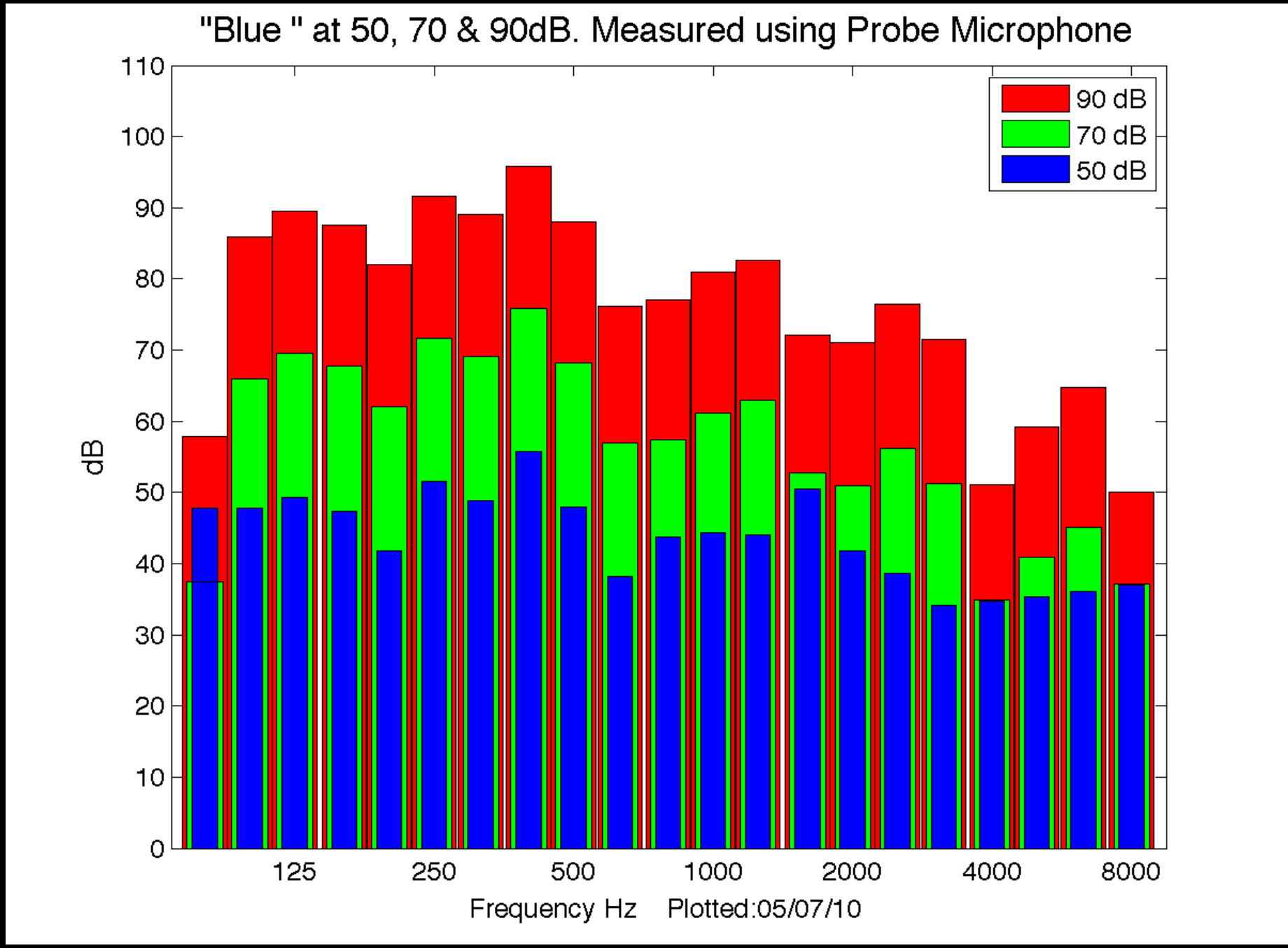

Signals at 1000Hz at 50, 70, 90dB. Measured using Probe Microphone
110
100
90
80
70
60
50
40
30
20
10
0
dB
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/07/10

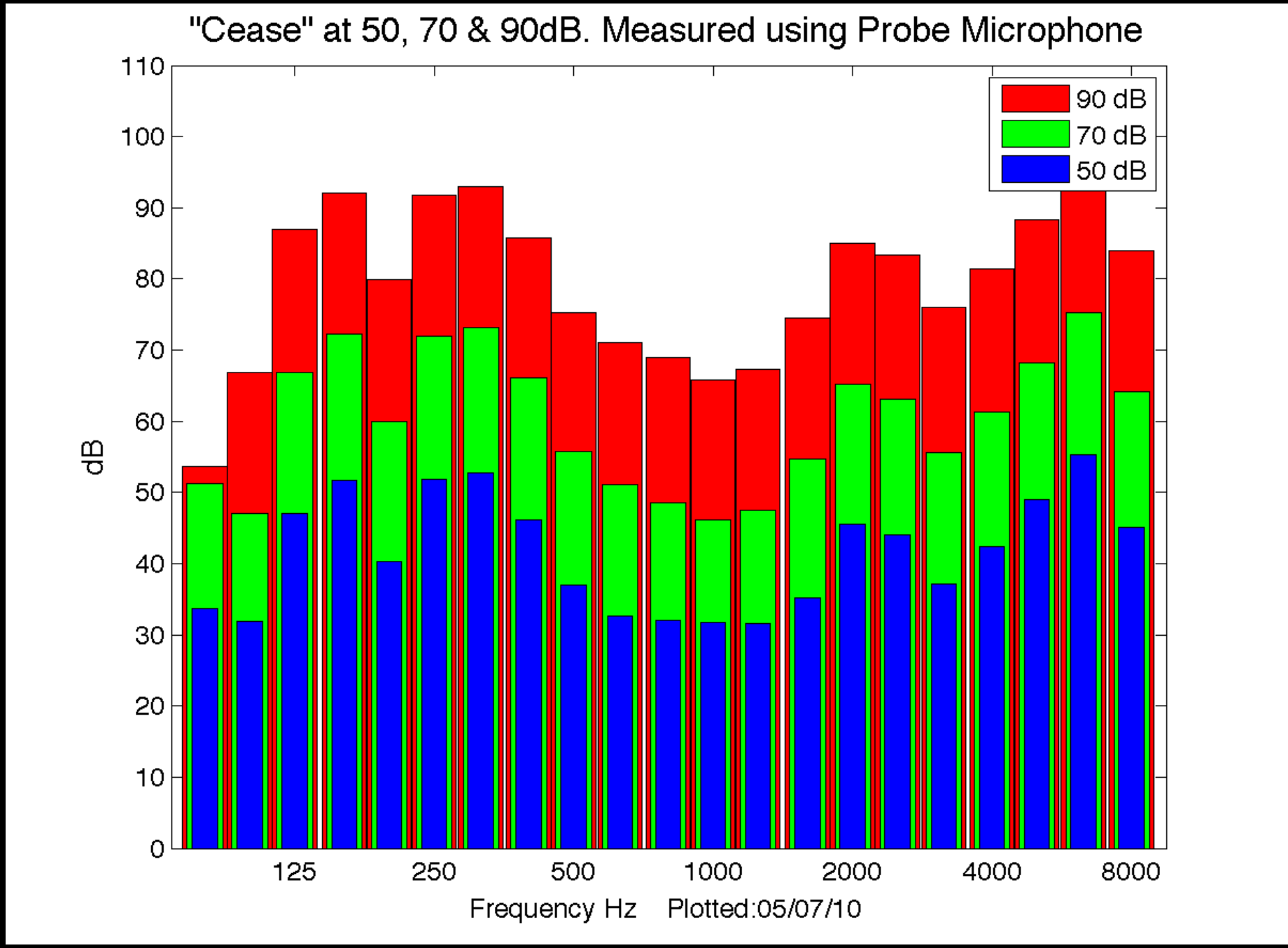

Signals at 2500Hz at 50, 70, 90dB. Measured using Probe Microphone
dB
110
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/07/10


Comparing Microphones in Free Field. Signal is the word "Hot"
Ref in Free Field
Probe in Free Field
Probe in Free Field with tissue
dB
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz Plotted:05/14/10


Showing the Effect of an Aid Turned Off using the Probe Mic. Signal is the word "H
Aided
Aid Turned Off
Free Field
dB
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/14/10


Effect of Aid and Elan Shell. Signal is the word "Hot"
Probe in Ear with Aid
Probe in Ear with Elan Shell
Probe in Free Field
dB
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/14/10


"Blue " at 50, 70 & 90dB. Measured using Probe Microphone
90 dB
70 dB
50 dB
dB
110
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/07/10


"Cease" at 50, 70 & 90dB. Measured using Probe Microphone
90 dB
70 dB
50 dB
dB
110
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Frequency Hz
Plotted:05/07/10

Section III

Speech as Criteria for Fitting Aids

What is speech?

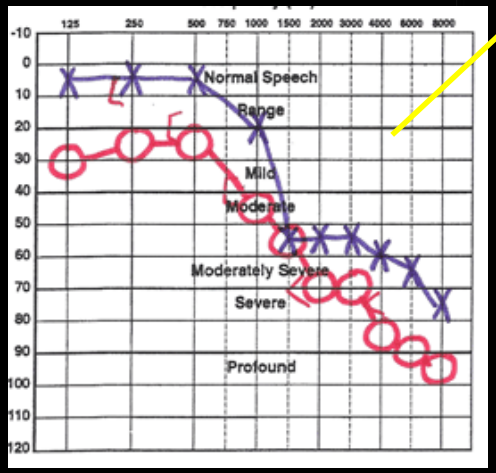
Textbook definition

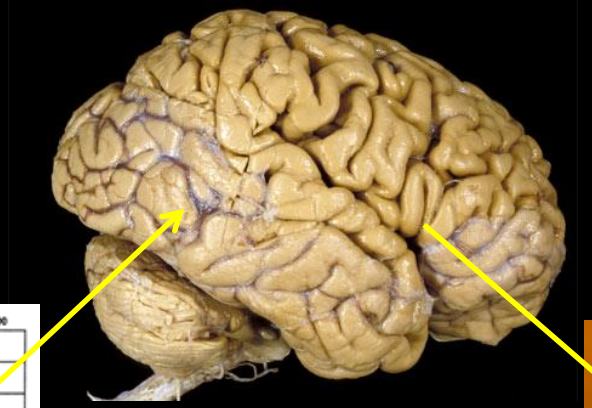
1. Frequency
2. Intensity
3. Duration

Additional information to give speech meaning

4. Intonation
5. Rhythm
6. Pause

Model for Speech Perception





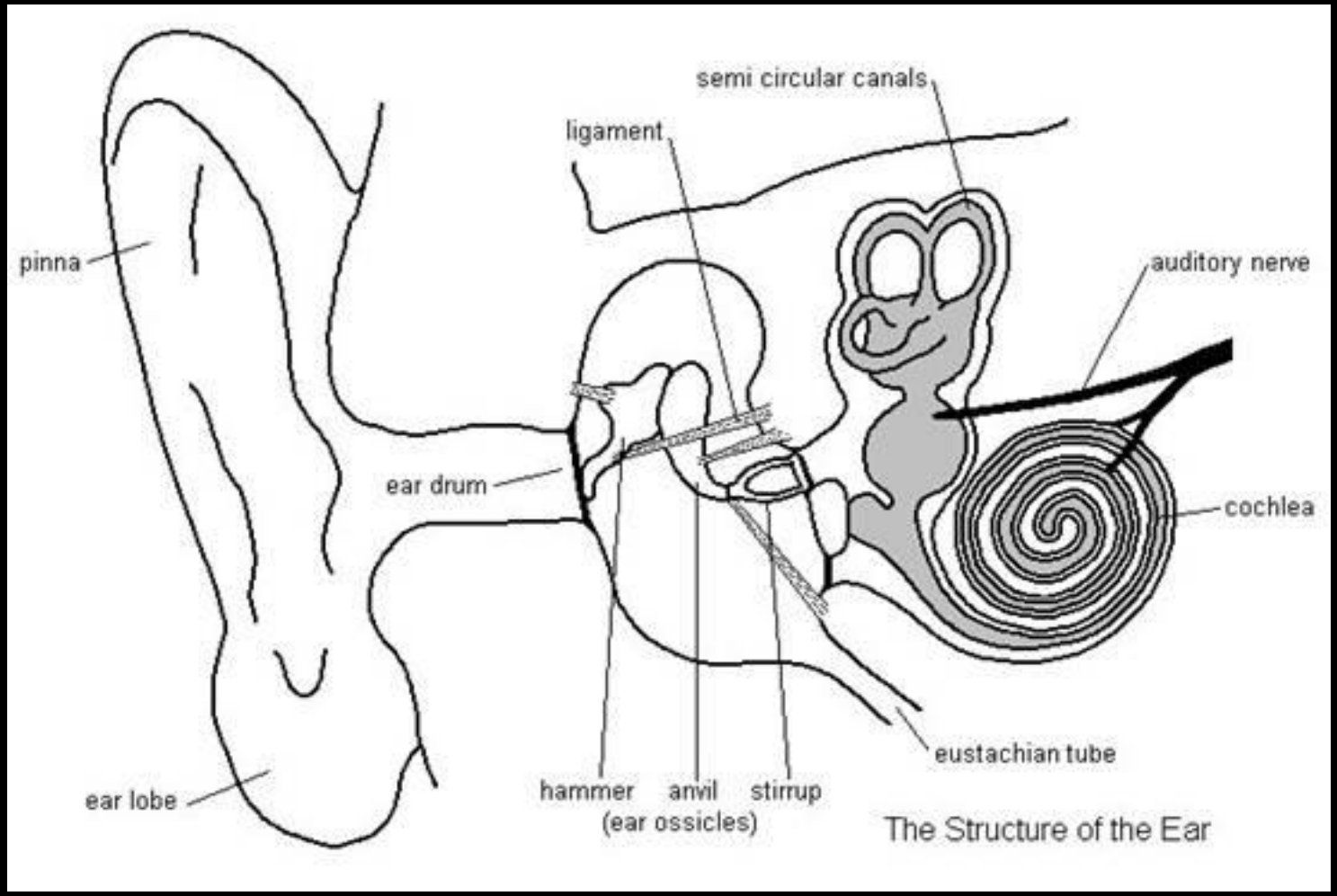
Input

1. Frequency
2. Intonation
3. Duration
4. Intensity
5. Rhythm
6. Pause

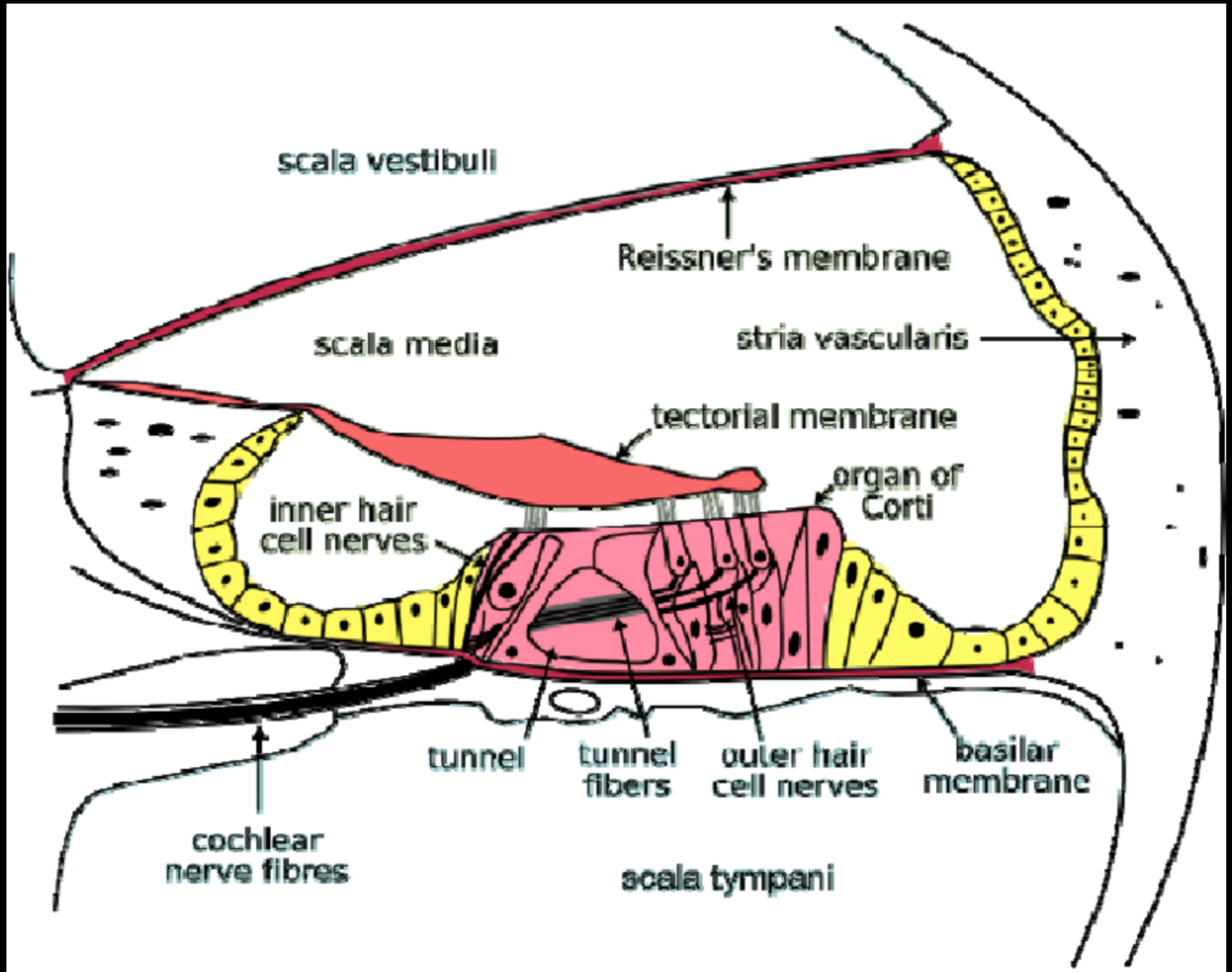
Output

1. Frequency
2. Intonation
3. Duration
4. Intensity
5. Rhythm
6. Pause

Structure of the Ear



Sound Wave → Outer Ear → Middle Ear → Inner Ear → to Brain

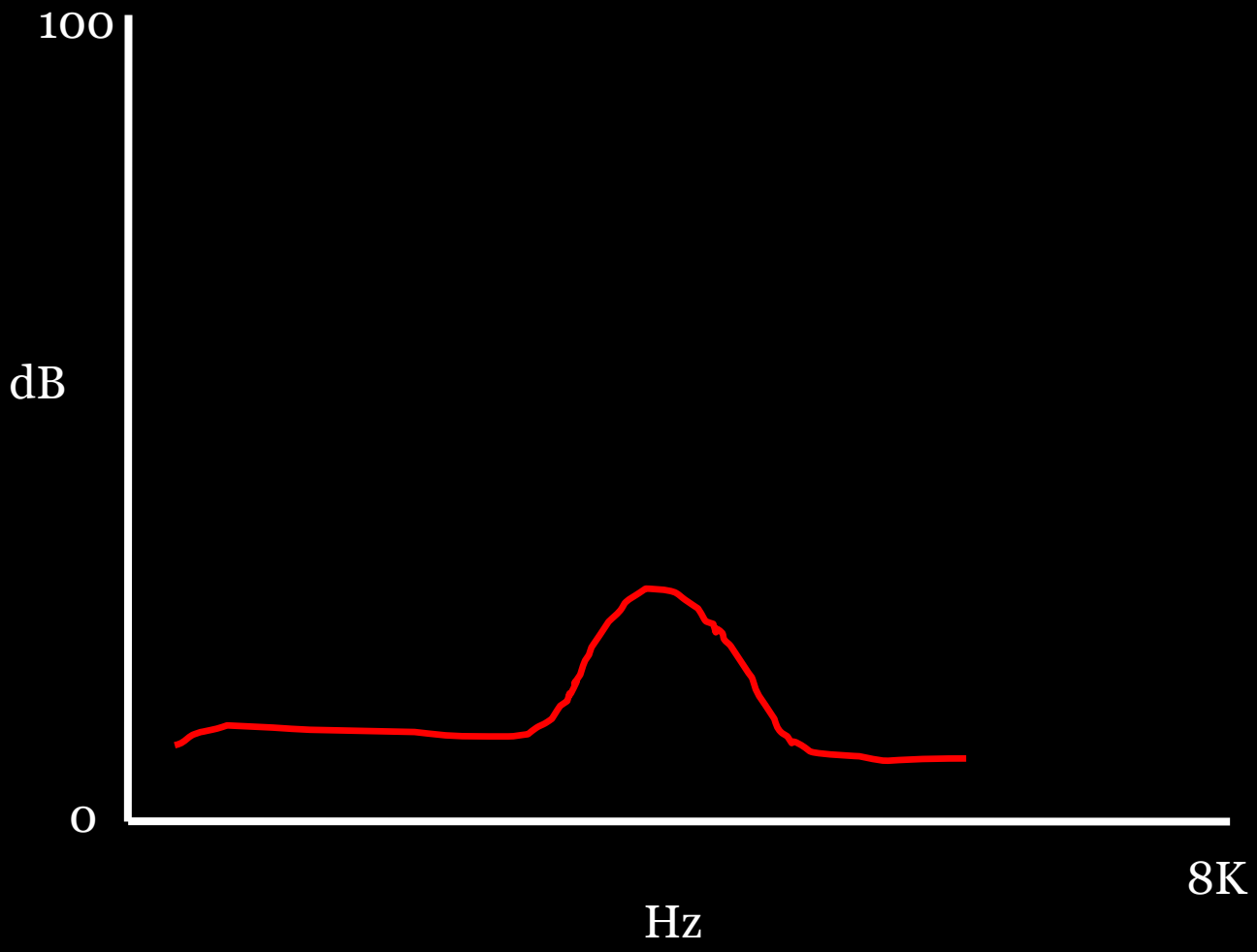

scala vestibuli
Reissner's membrane
scala media
stria vascularis
tectorial membrane
organ of Corti
inner hair cell nerves
tunnel
tunnel fibers
outer hair cell nerves
basilar membrane
cochlear nerve fibres
scala tympani

Structural Affects

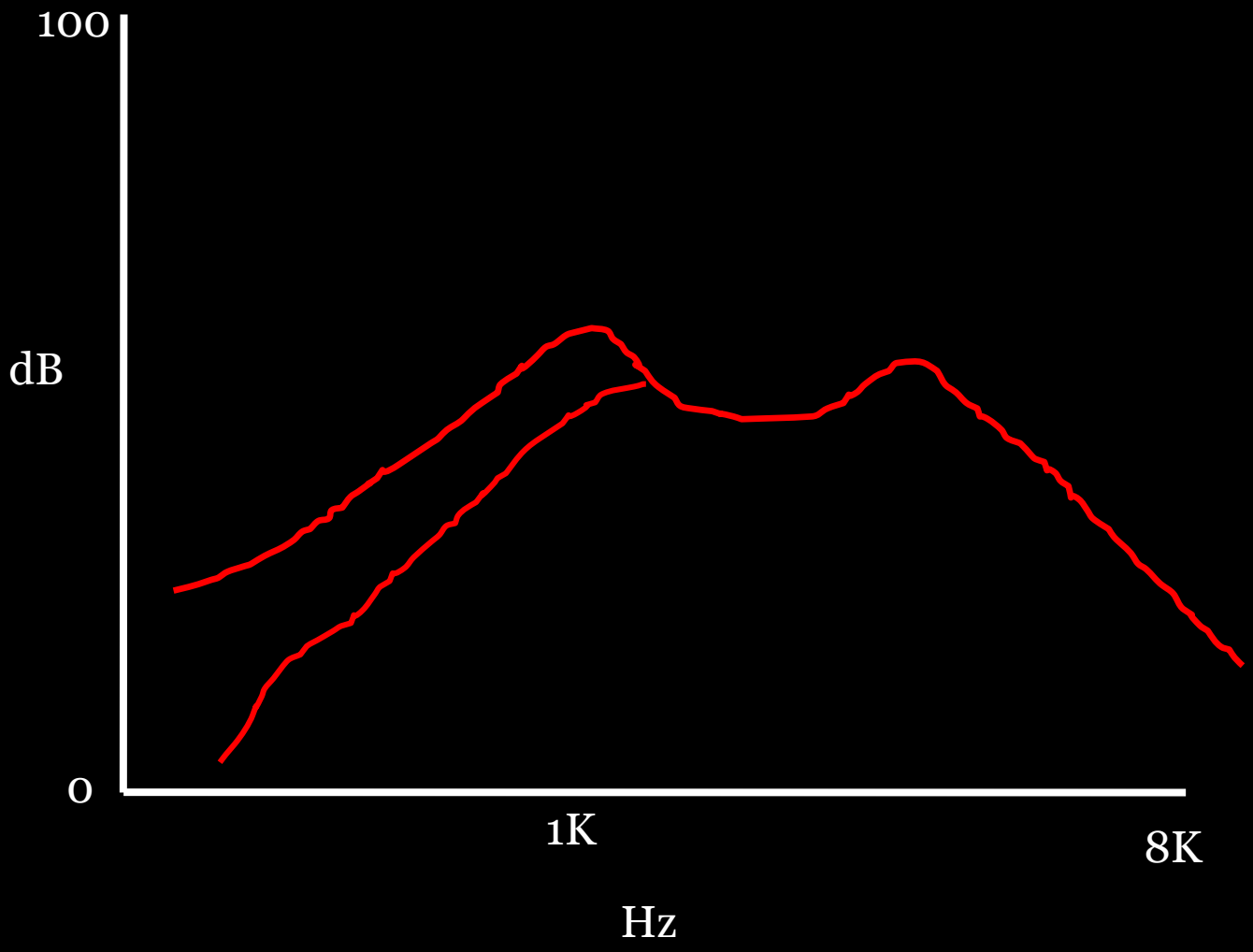
What affect do each of these parts of the ear have on the speech signal?

1. Resonant frequency of the ear canal
2. Middle-ear conditions
3. Inner-ear nerve damage

Resonant Frequency of the Ear Canal



Effects of Venting the Earmold

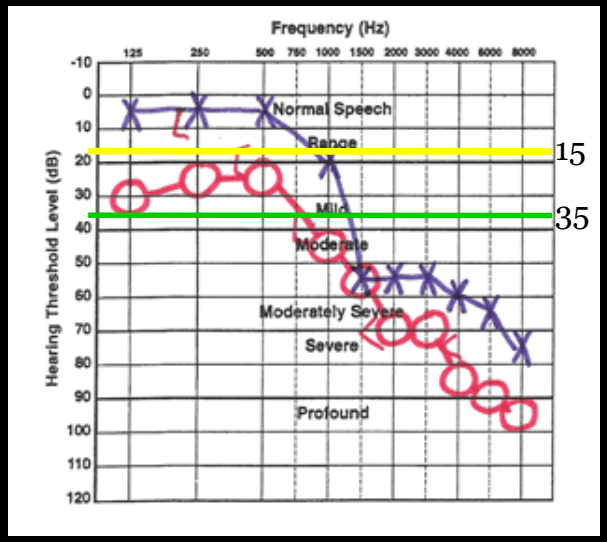


Basis for Research

- Observations over the years

- Research Question: What information in the speech signal is the brain using to structure the whole?

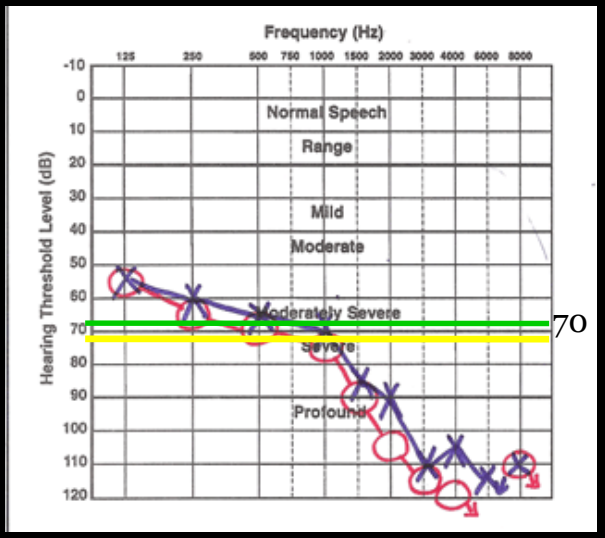
HTL Audiogram



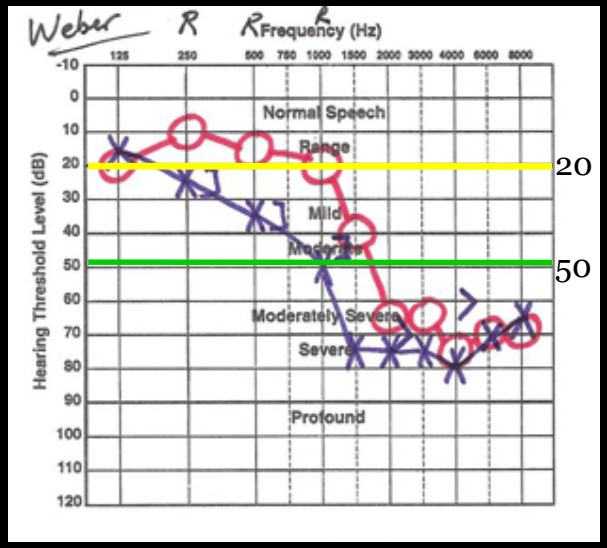
Participant 101

Right Ear SRT

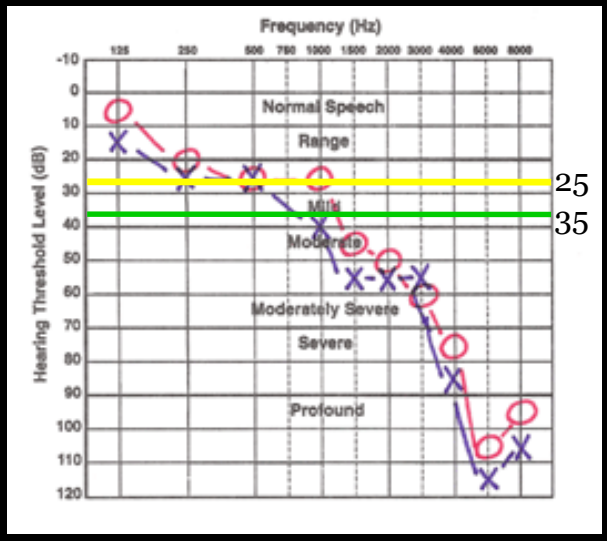
Left Ear SRT



Participant 102



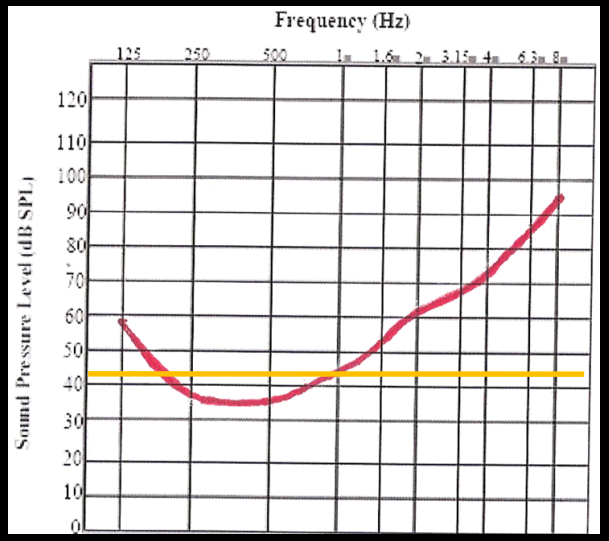
Participant 103



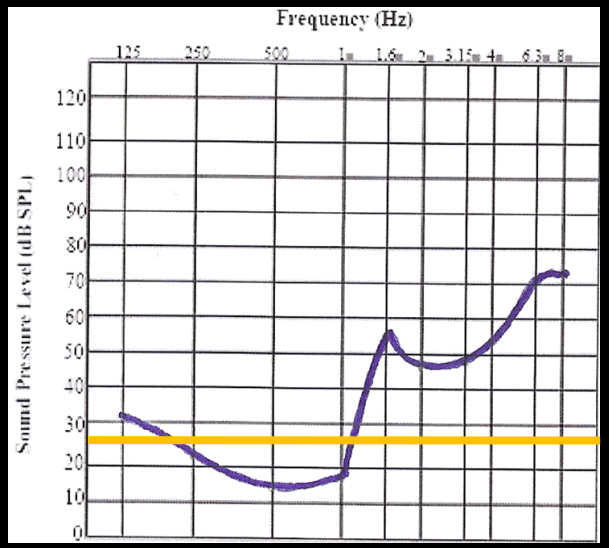
Participant 104

HTL & SPL Audiograms

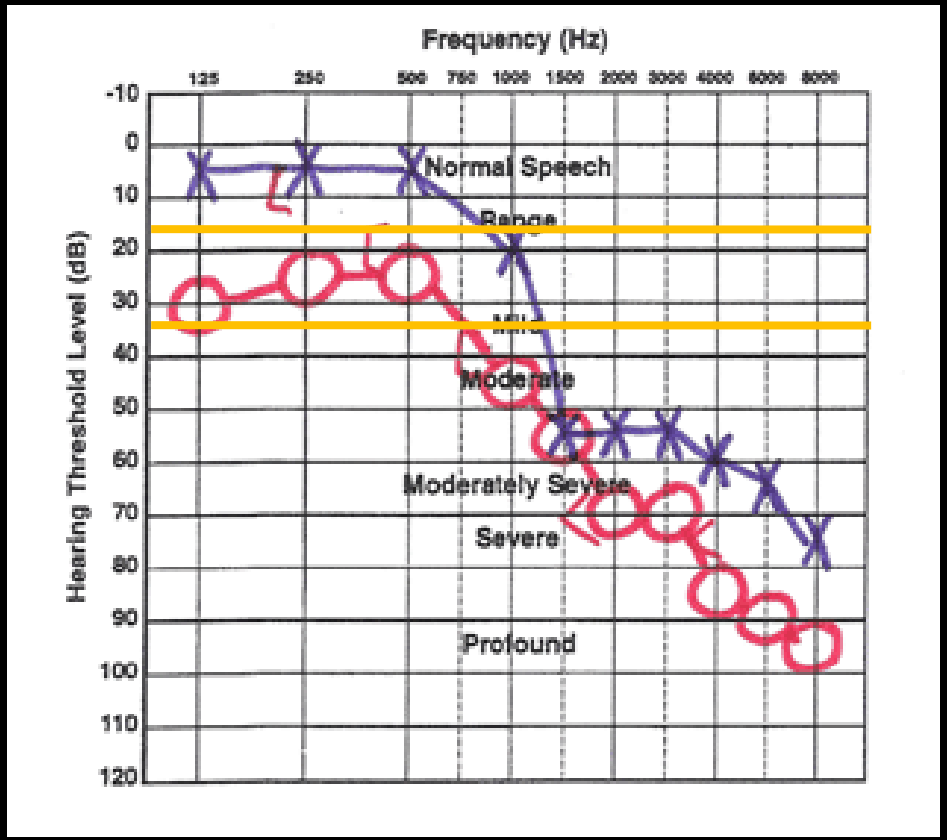
Participant 101



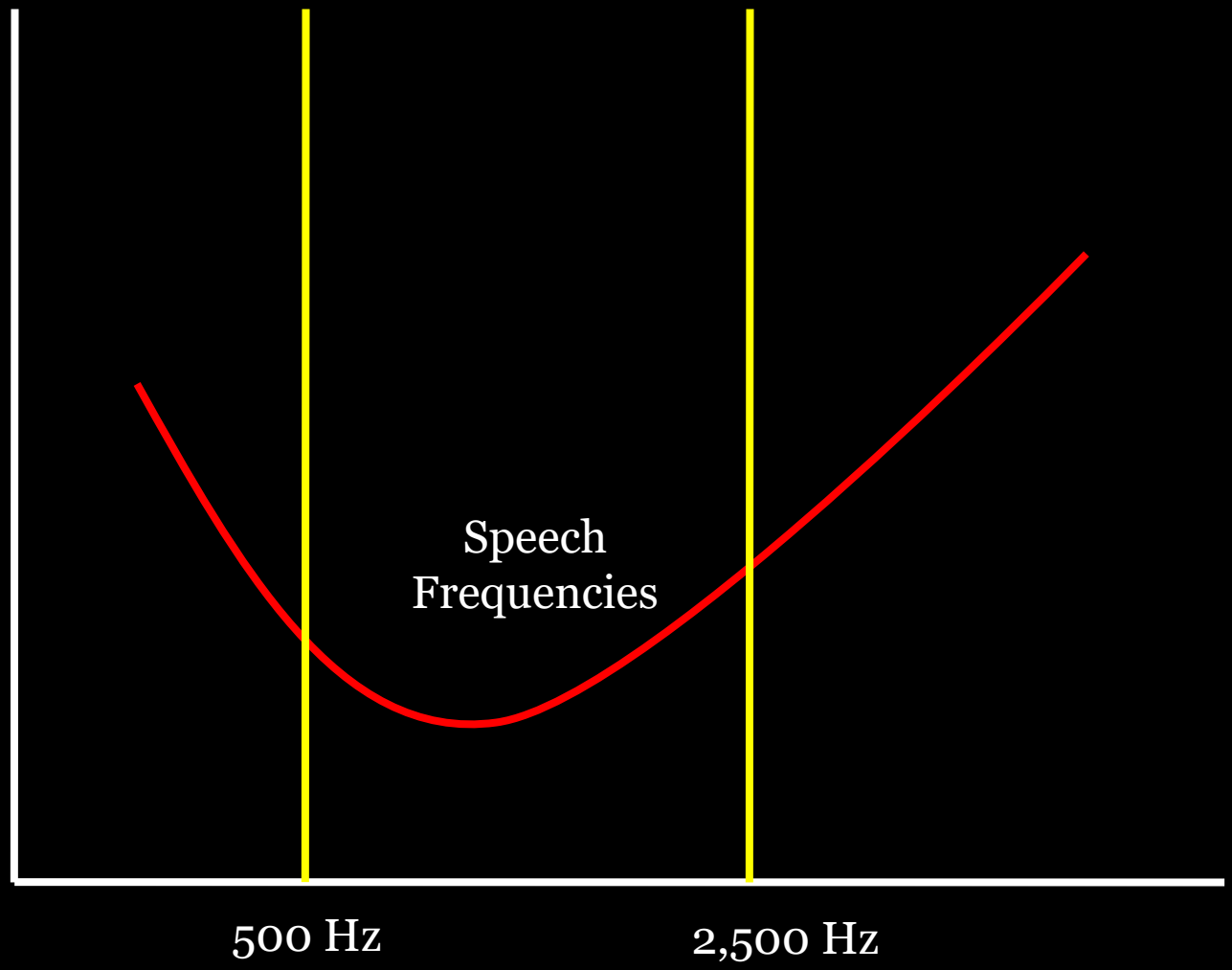
Right Ear at 45°



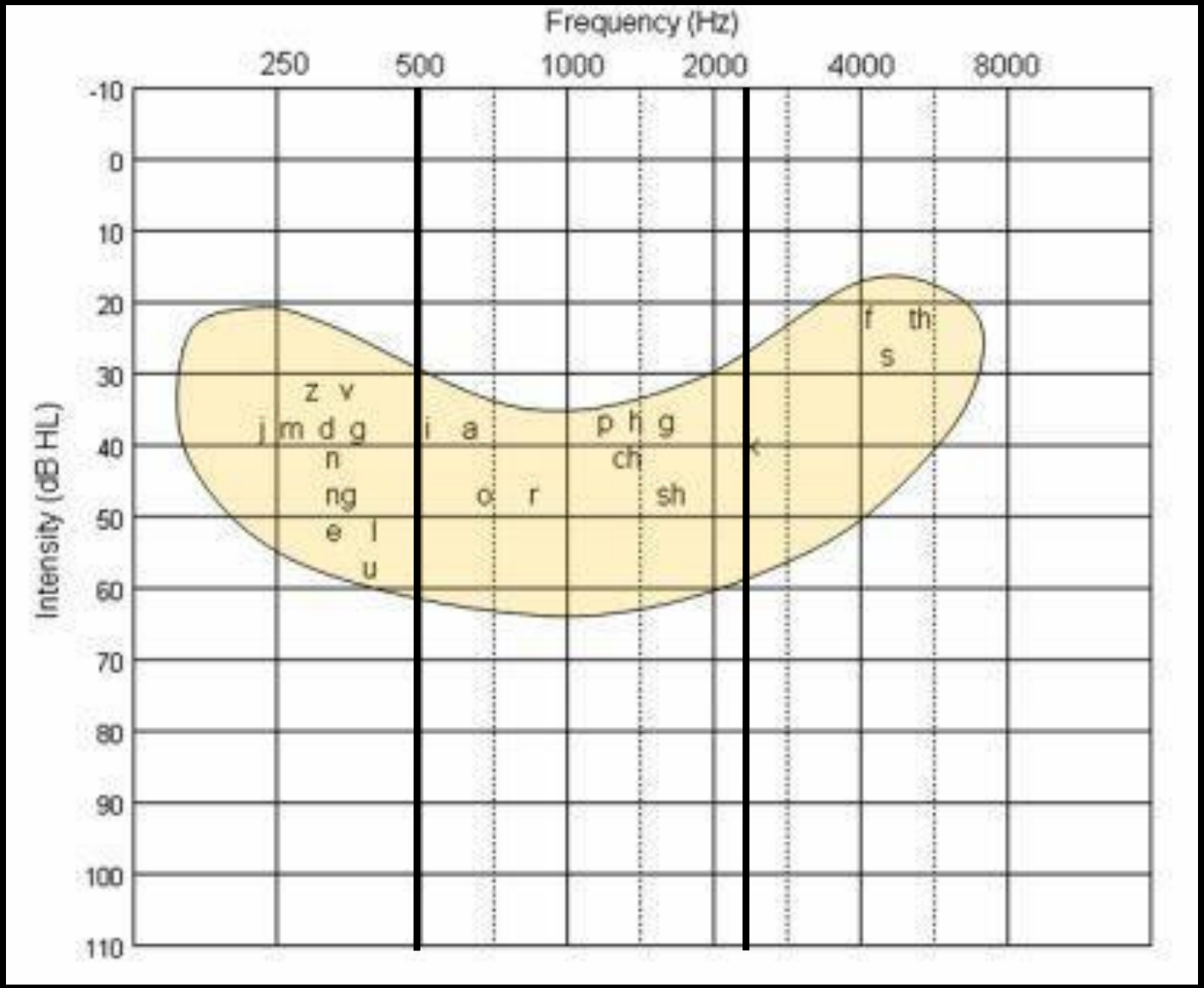
Left Ear at 45°



Speech Frequency Curve

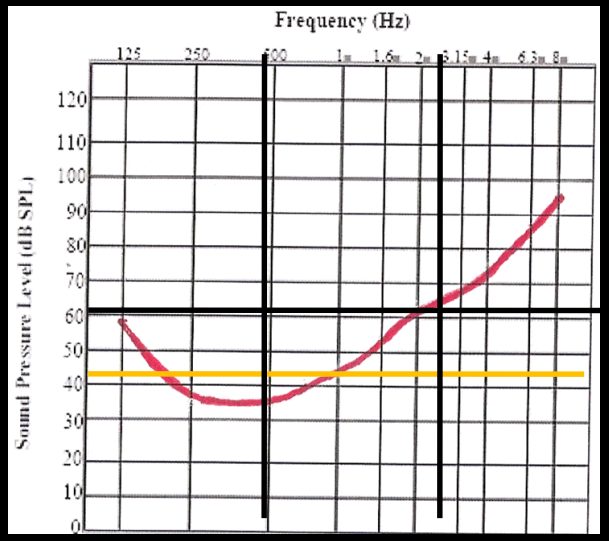


Banana Curve

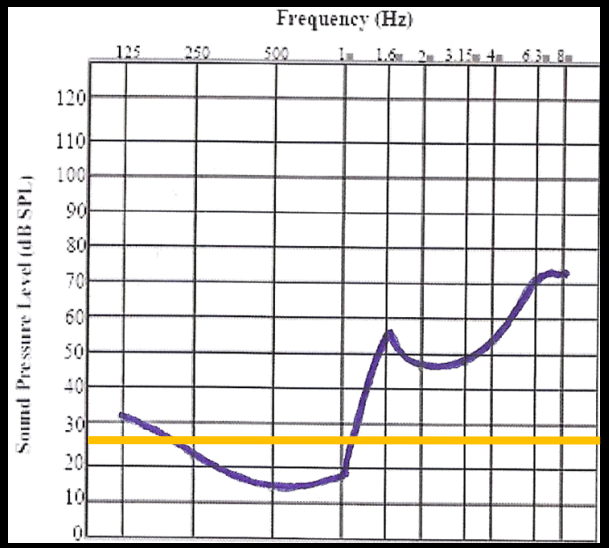


HTL & SPL Audiograms

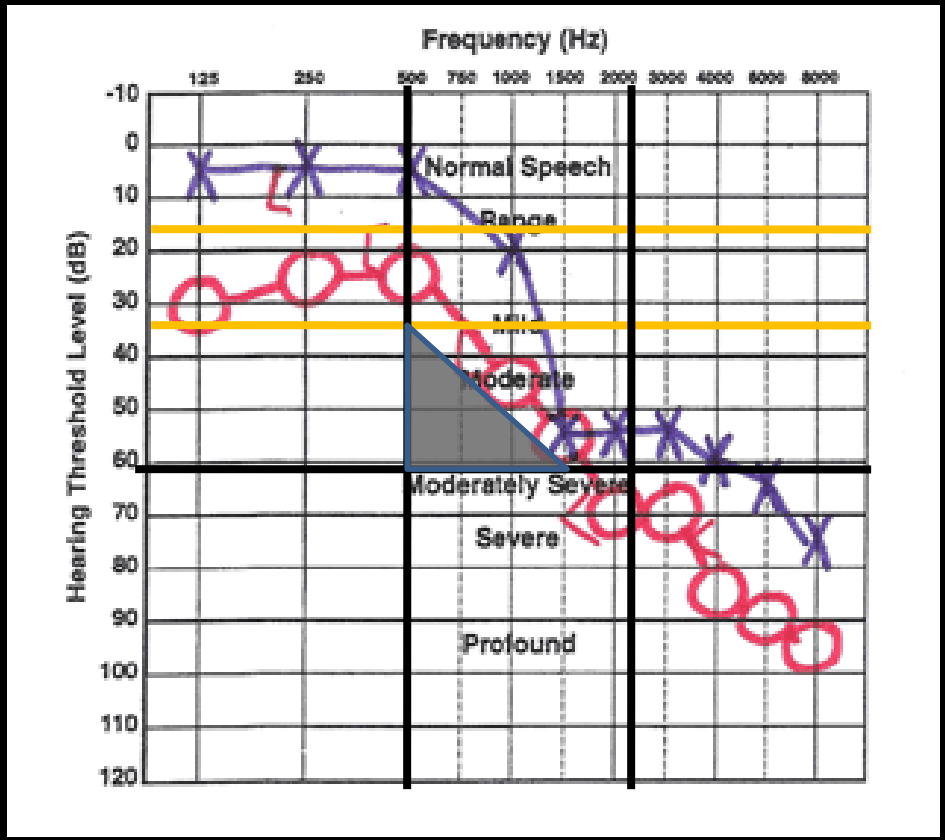
Participant 101



Right Ear at 45°



Left Ear at 45°



Theories of Hearing

- Telephone Theory
- Volley Theory
- Pattern Theory
- Stationary Wave Theory
- Traveling Wave Theory
- Resonance Theory
- Place theory
- Temporal theory
- Frequency Theory

Theories of Formula Fits

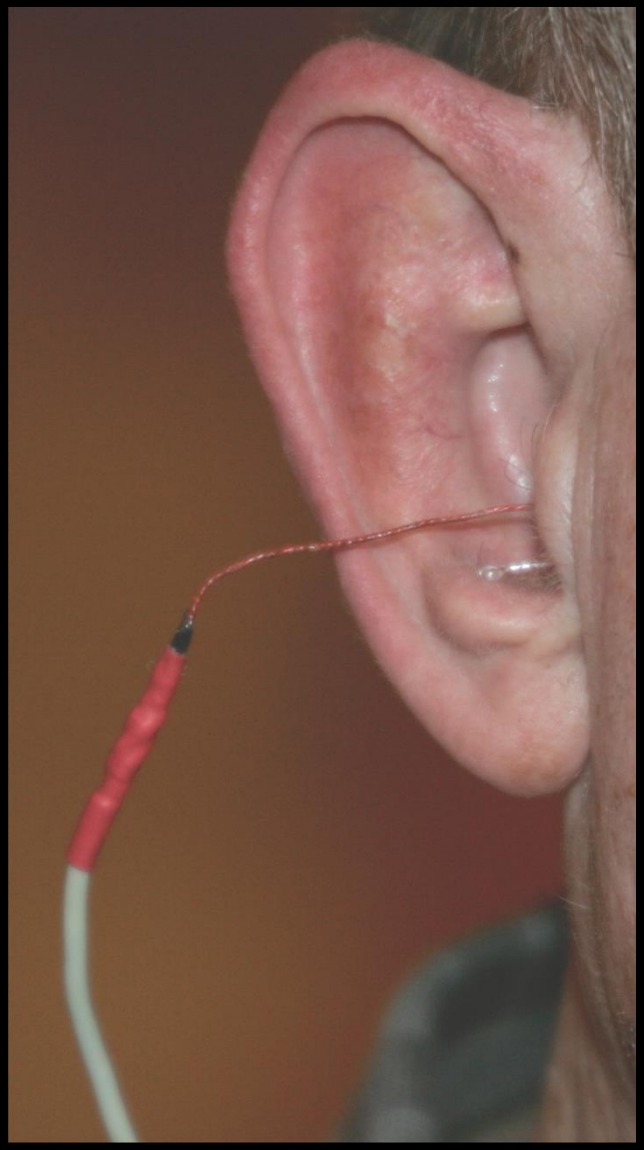
- NAL-R
- NAL-NL 1
- POGO
- Libby 1/3-2/3
- DSL
- BAFA

Most of these are based on how much intensity is needed at specific frequencies to compensate for the hearing loss.

Section IV

Procedure for Collecting Data

Microphone Placement

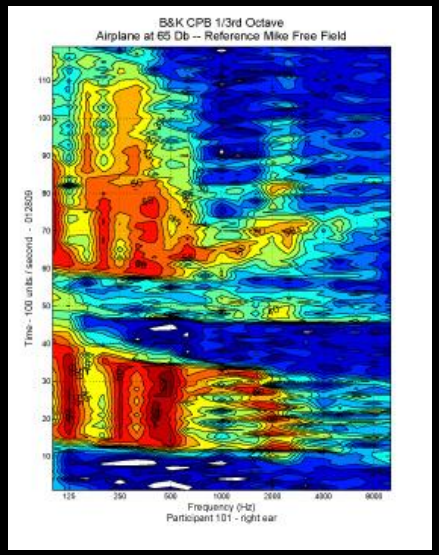


Probe microphone in the ear

Probe microphone outside the ear

Types of Data

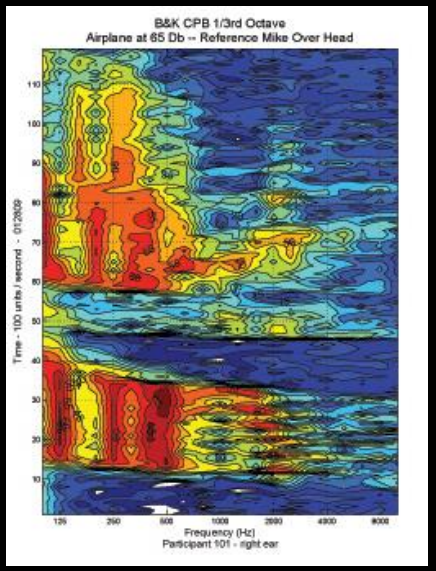
B&K CPB 1/3 Octave Analysis

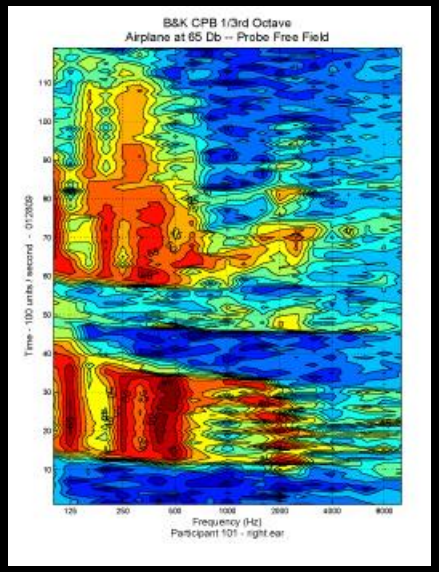


Airplane at 65 dB

Reference Microphone

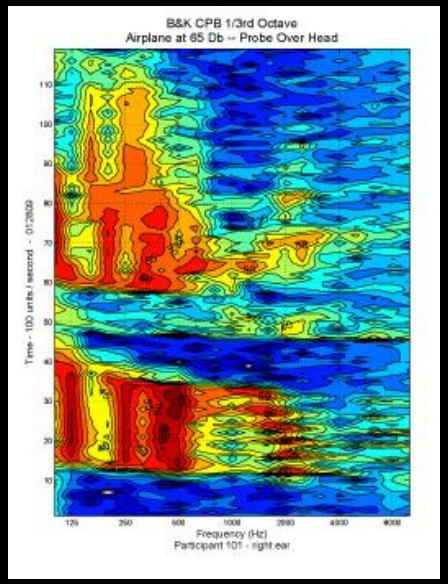
Free field Overhead





Probe Microphone

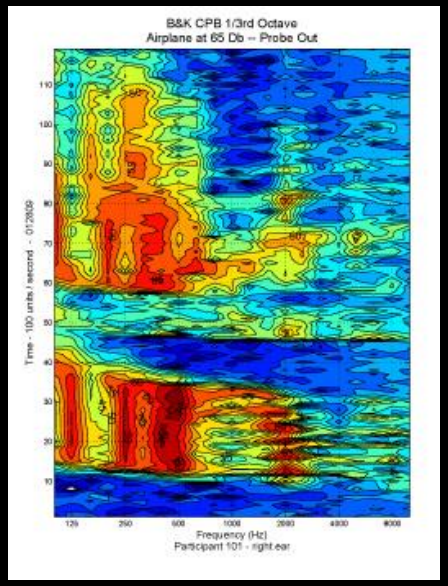
Free field Overhead



Types of Data

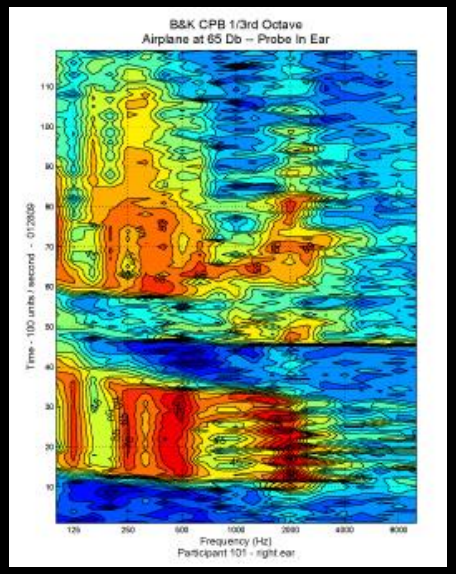
B&K CPB 1/3 Octave Analysis

Airplane at 65 dB

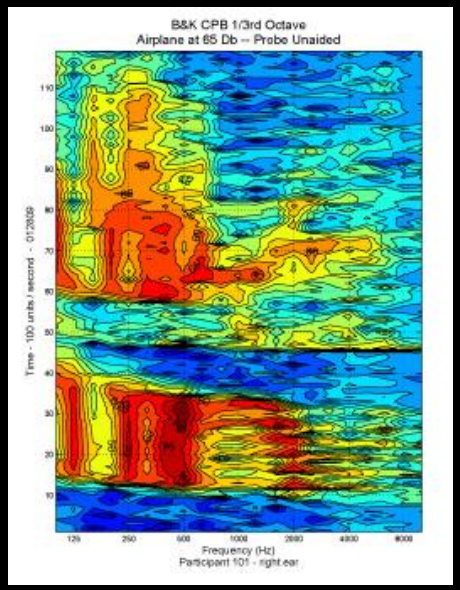


Probe Microphone

Outside Ear

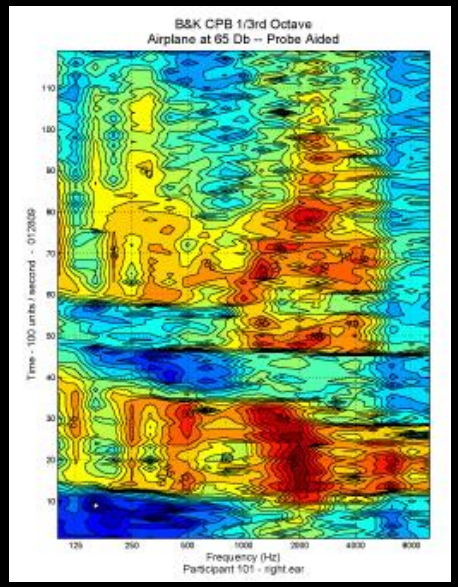


Inside Ear



Probe Microphone

Unaided



Aided

Analyses Used in Testing

1. Constant Percentage Bandwidth (CPB)
2. Fast Fourier Transform (FFT)
3. Word spectrum
4. Fundamental frequency and formants of vowels with and without inflection

Analyses Used in Testing

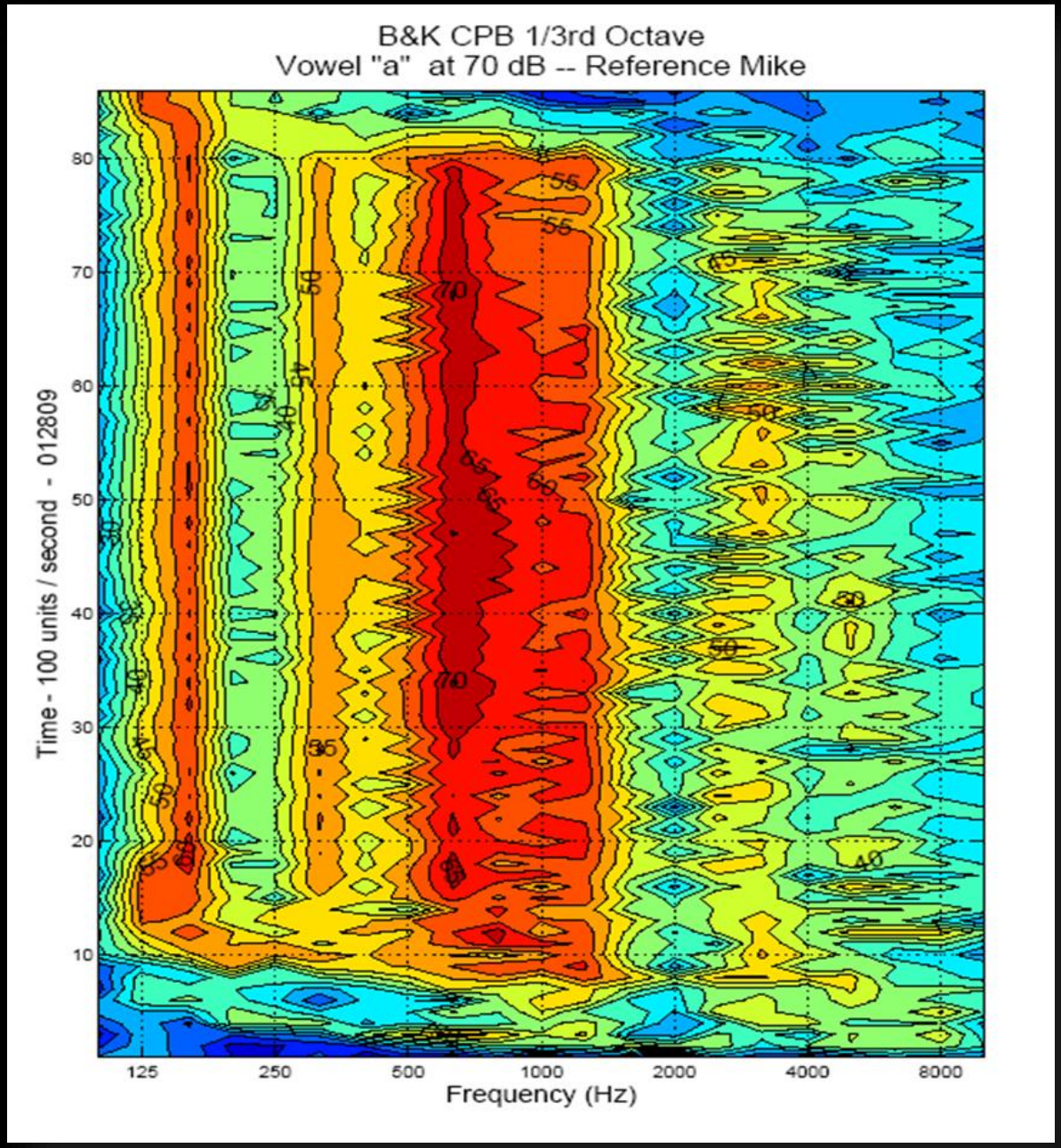
5. Linear Predictive Coding (LPC)

6. Comparison of word spectrum to patient's Sound Pressure Level (SPL).
   - *Comparisons made at the patient's Speech Reception Threshold (SRT) and normal conversation, or 65 dB.*

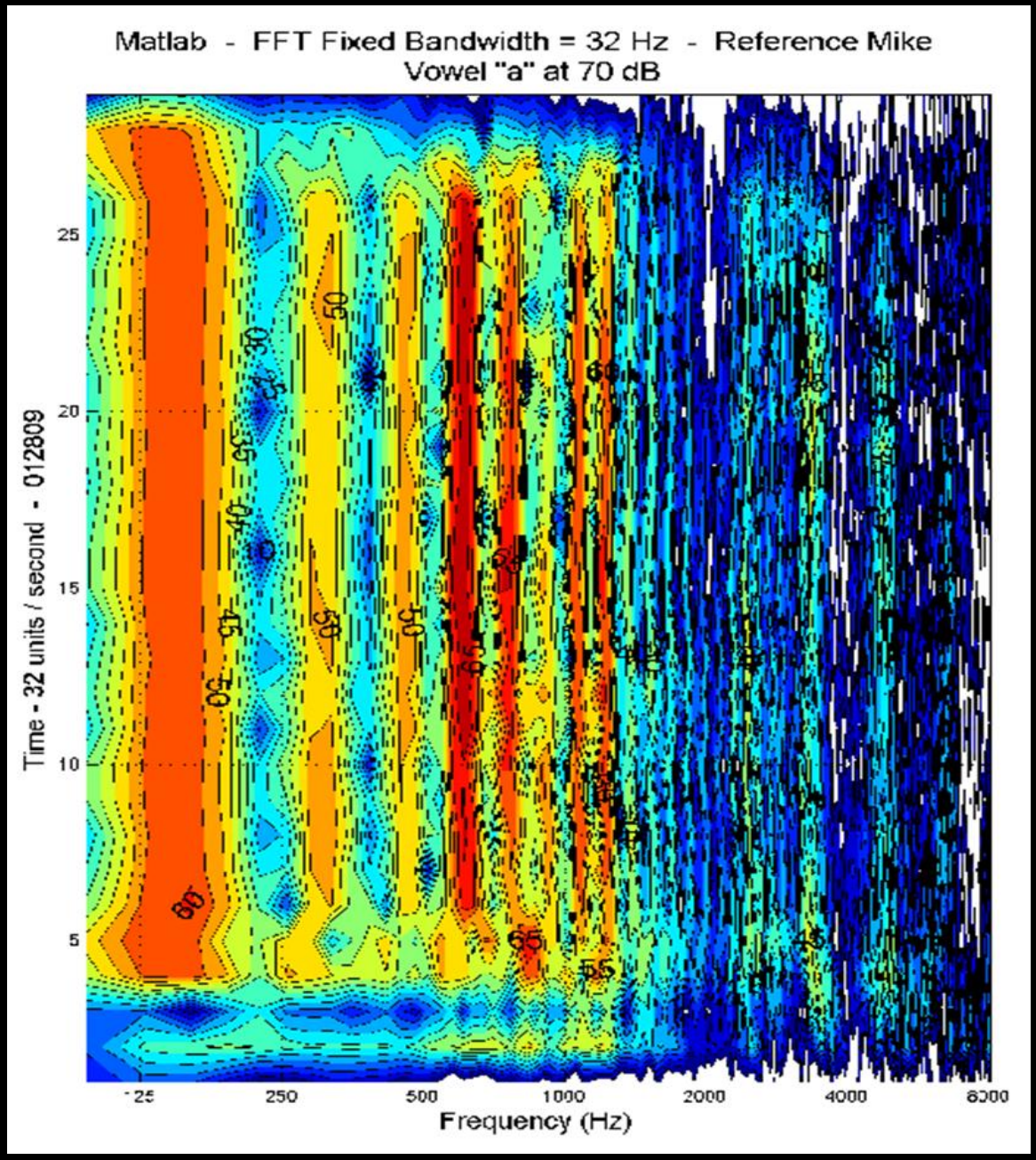
Formant and Fundamental Frequency Table

Acoustic Analysis of Speech by Kent and Read

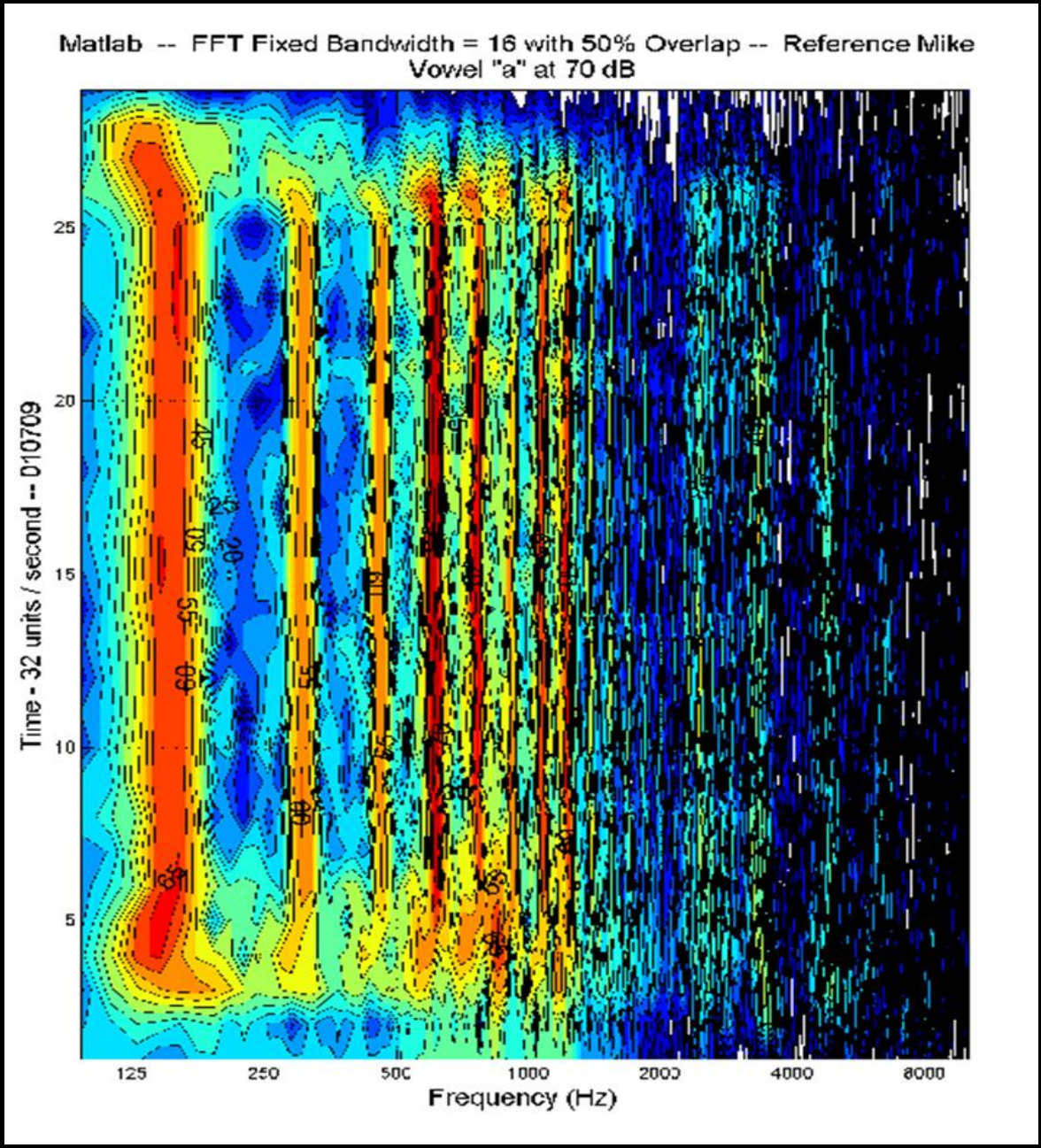
Fundamental & Formant	Vowel u	o	a	e	i
f_0	137	120	124	120	130
f_1	333	454	627	449	294
f_2	1190	1206	1018	2077	2275
f_3	2306	2359	2404	2672	2964



CPB 1/3 Octave of vowel “a” at 70dB



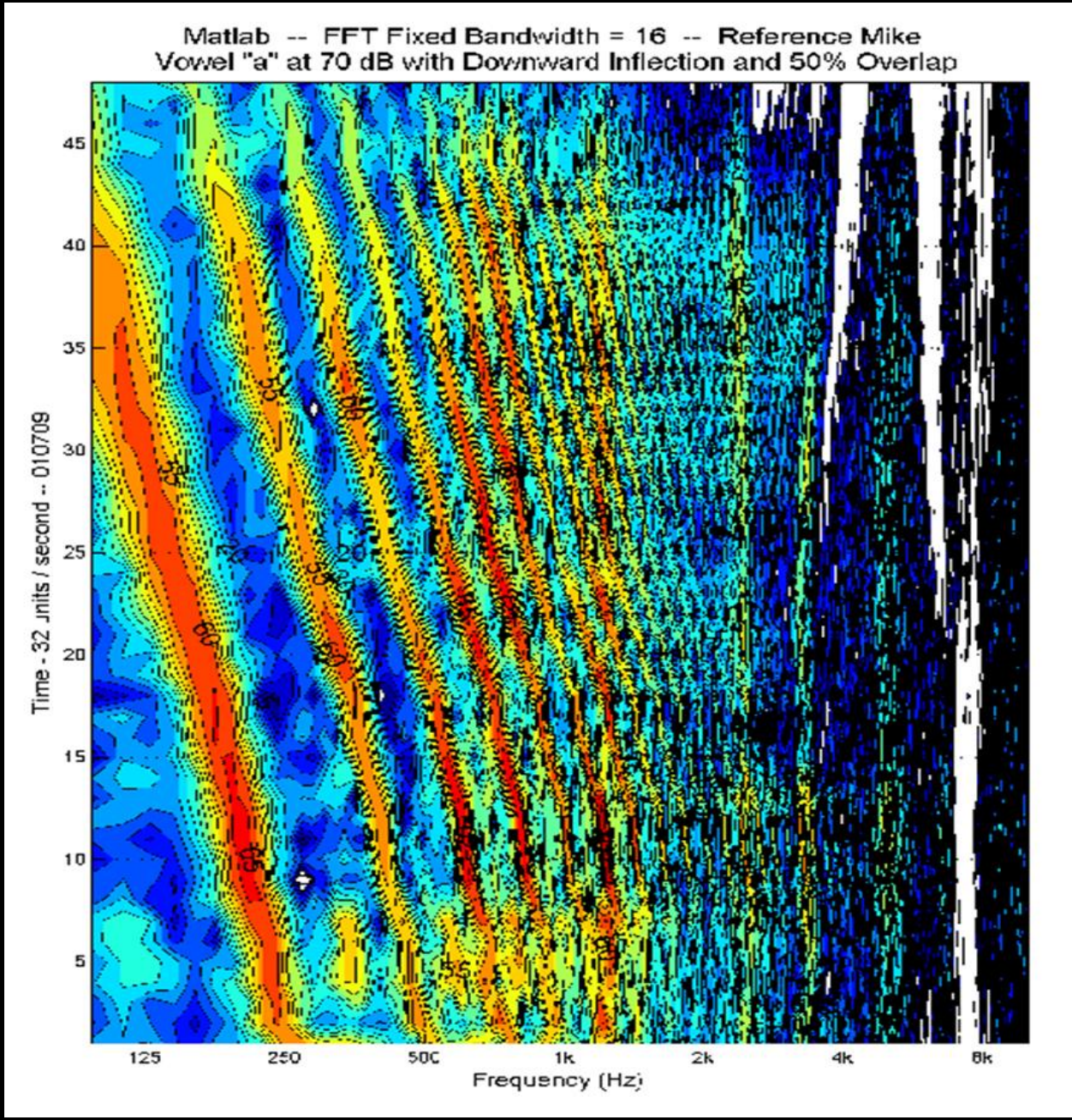
FFT of vowel “a” at 70dB



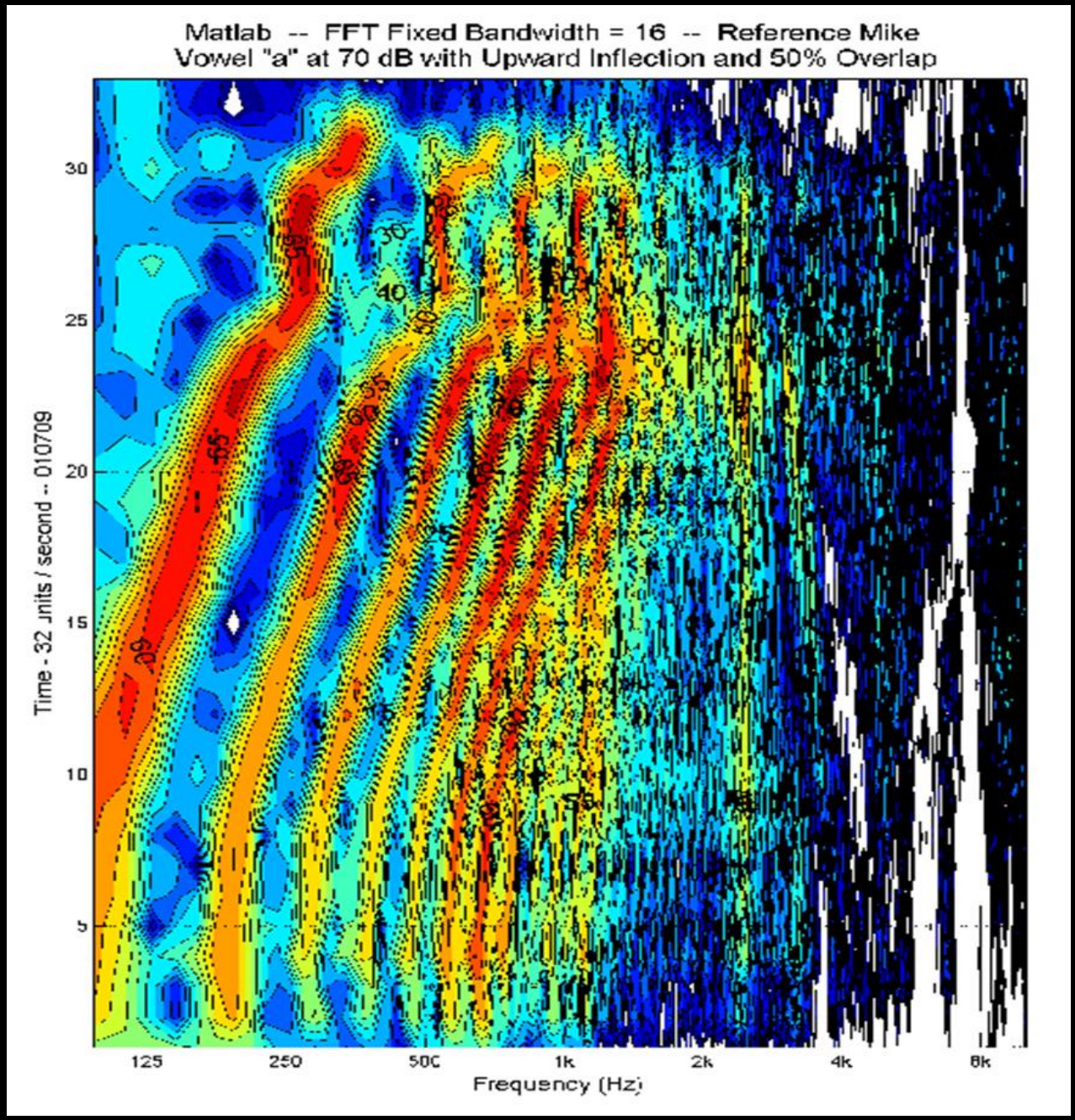
FFT at 16 of vowel “a” at 70dB

Fundamental Frequency and Formant Estimates – LPC

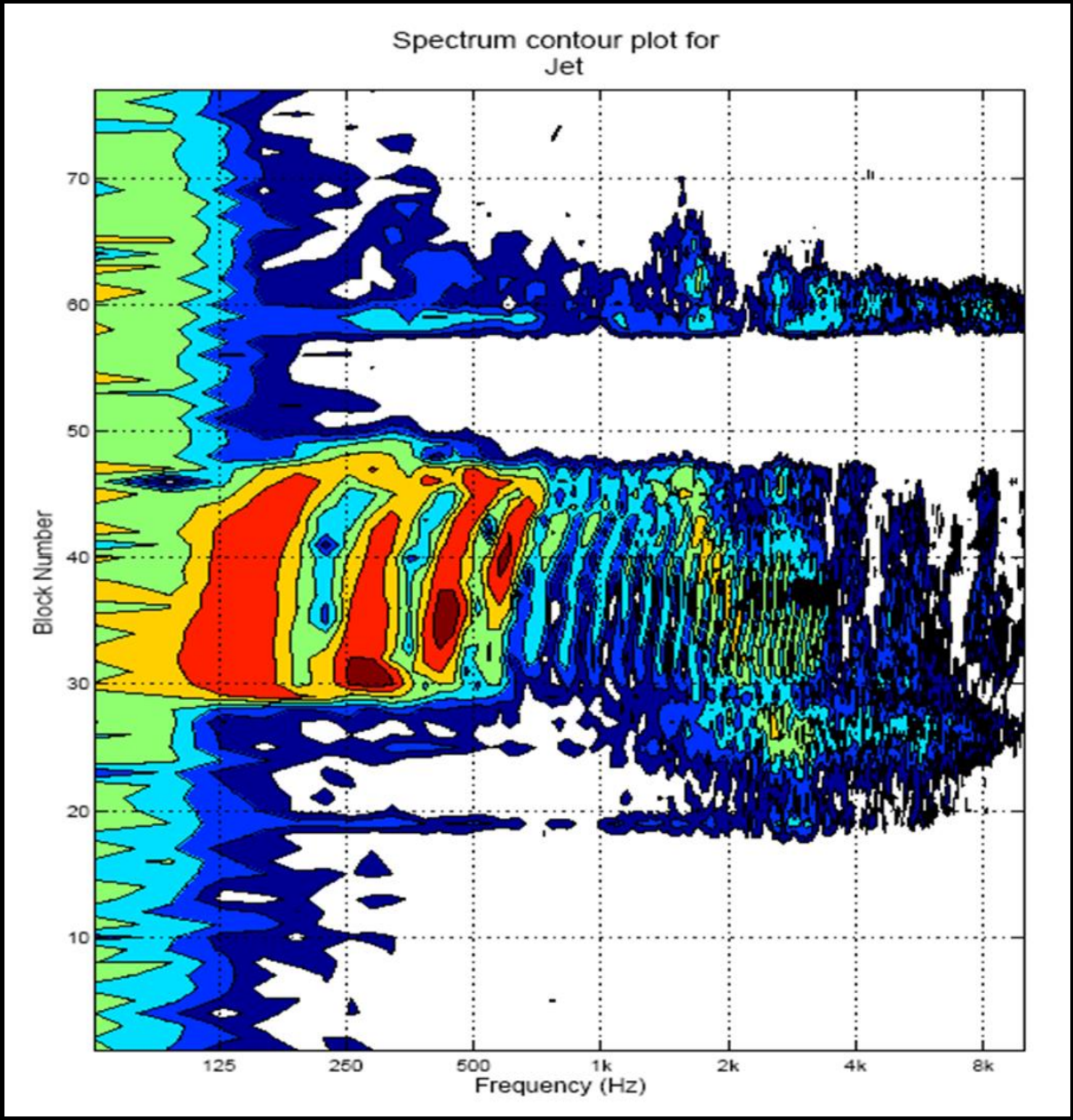
Formants	Vowels				
	u	o	a	e	i
0	165	149	152	152	165
1	326	535	643	497	322
2	1166	990	1171	2166	2433
3	2473	2542	2513	2649	3015
4	3143	3214	3362	3450	3766
5	4701	4378	4766	4927	4742
6	5442	5549	5414	5017	5317
7	6474	6316	6443	6579	6678



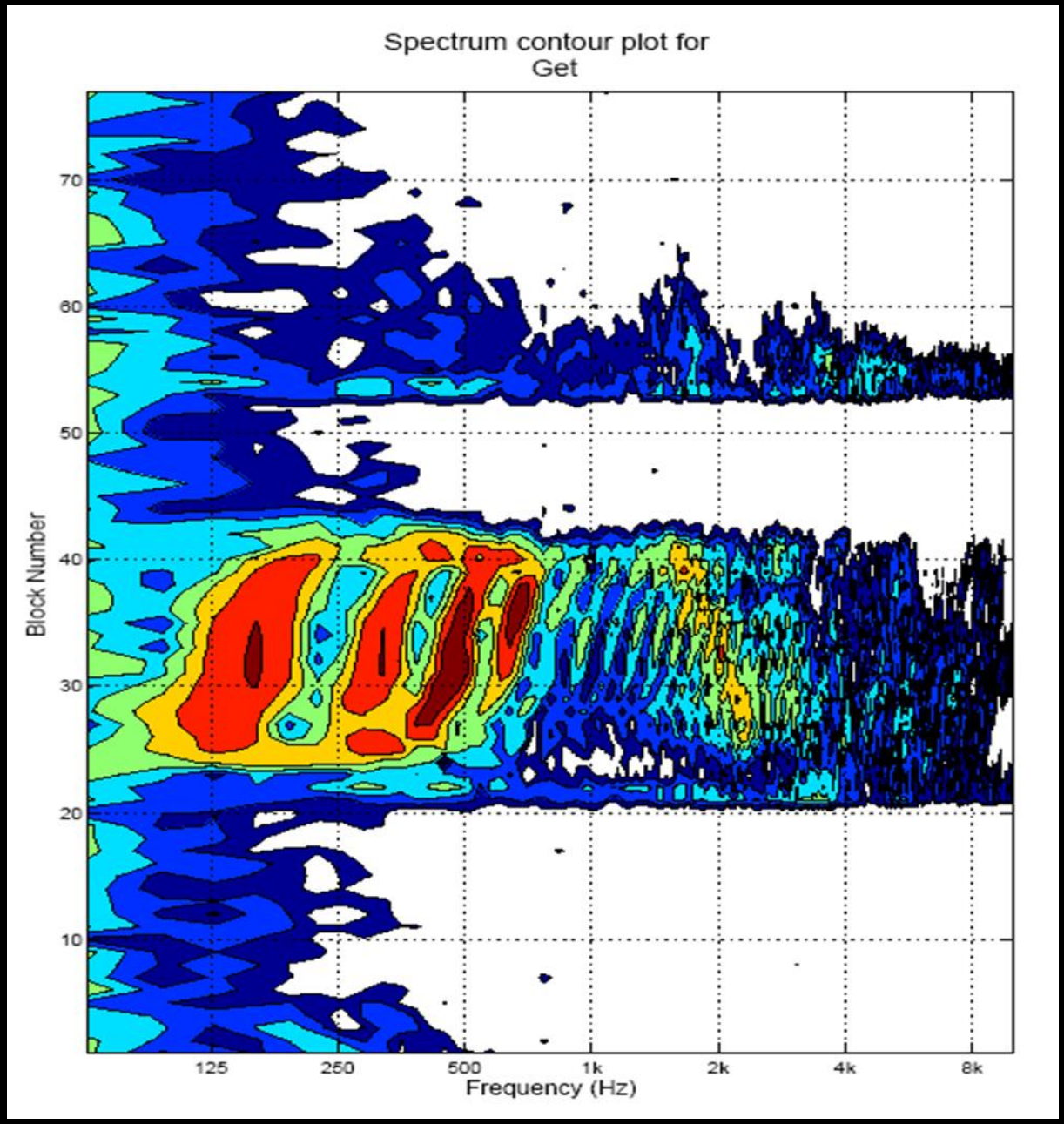
MatLab FFT Analysis of “a” with downward inflection



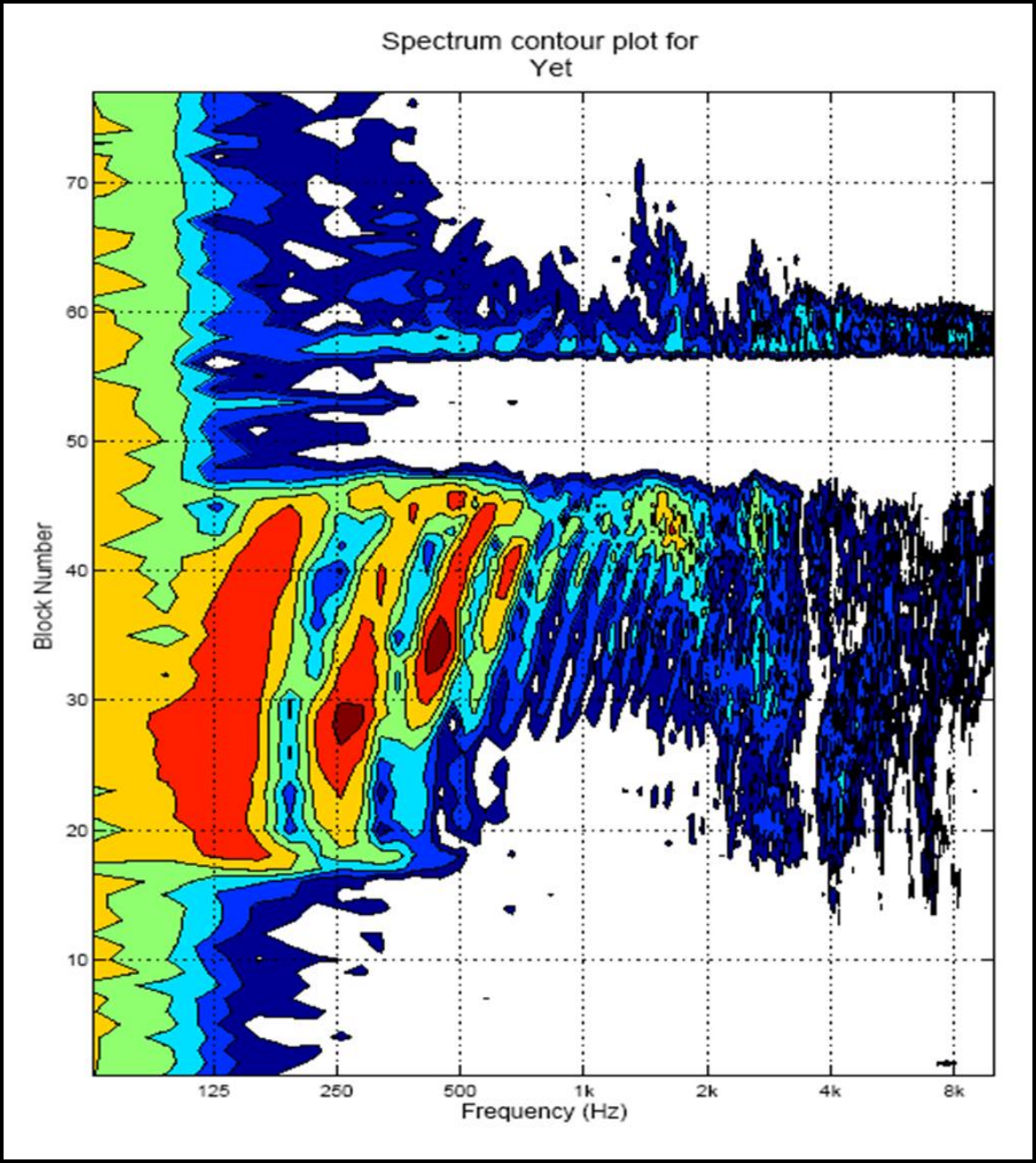
MatLab FFT Analysis of “a” with upward inflection



Spectrum Contour for Jet



Spectrum Contour for Get



Spectrum Contour for Yet

Section V

Rationale for Bessel's Word List

Frequency Analysis of Thirty Bessel Words

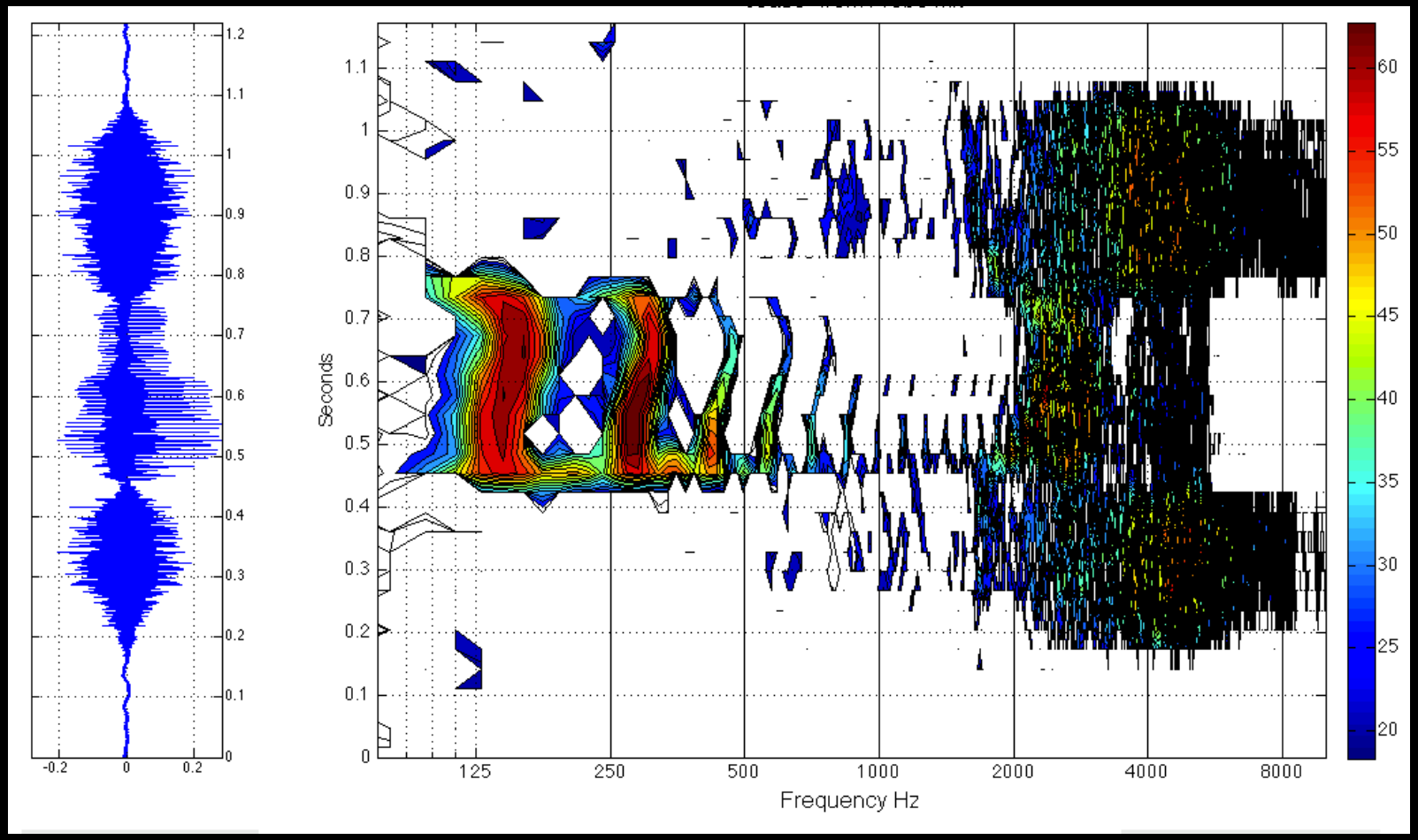
Introduction

BHSS incorporates the use of use words vs. simple pure tones in its assessment of patients' hearing loss. Words cluster into groups with different amounts of energy at various frequencies. Words chosen to archetypical of each grouping are used in hearing evaluations. Sue Bessel Hume proposed 30 of such words (Bessel 1978). At BHSS, John Berry, using a high quality microphone at 44.1k points per second, has recorded these words. These sound files were analyzed using the FFT algorithm in Matlab using a fixed 21.53 Hz bandwidth. Then, the total energy at groups of frequencies within the word was computed. This information quantitative information was compared to the ranking of the information as perceived by Sue Bessel in her dissertation

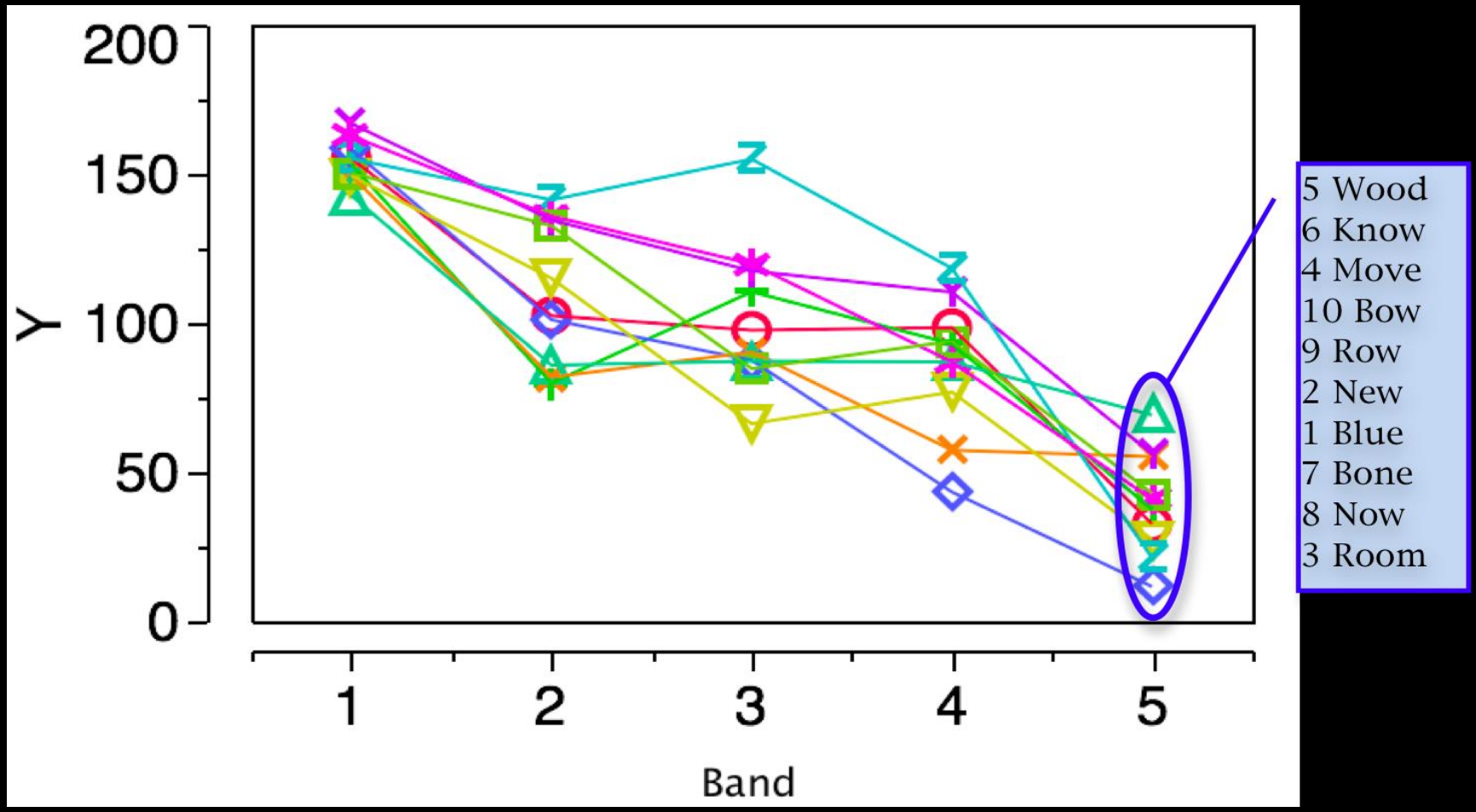
Example Word – "Seek"

Figure 1 shows a contour plot of the word across frequency and over time. Figure 2 shows how the word was sectioned into frequency bands as shown. The total power in the band is calculated by summing the energy in dB in each non-zero 0.046-second interval in that band.

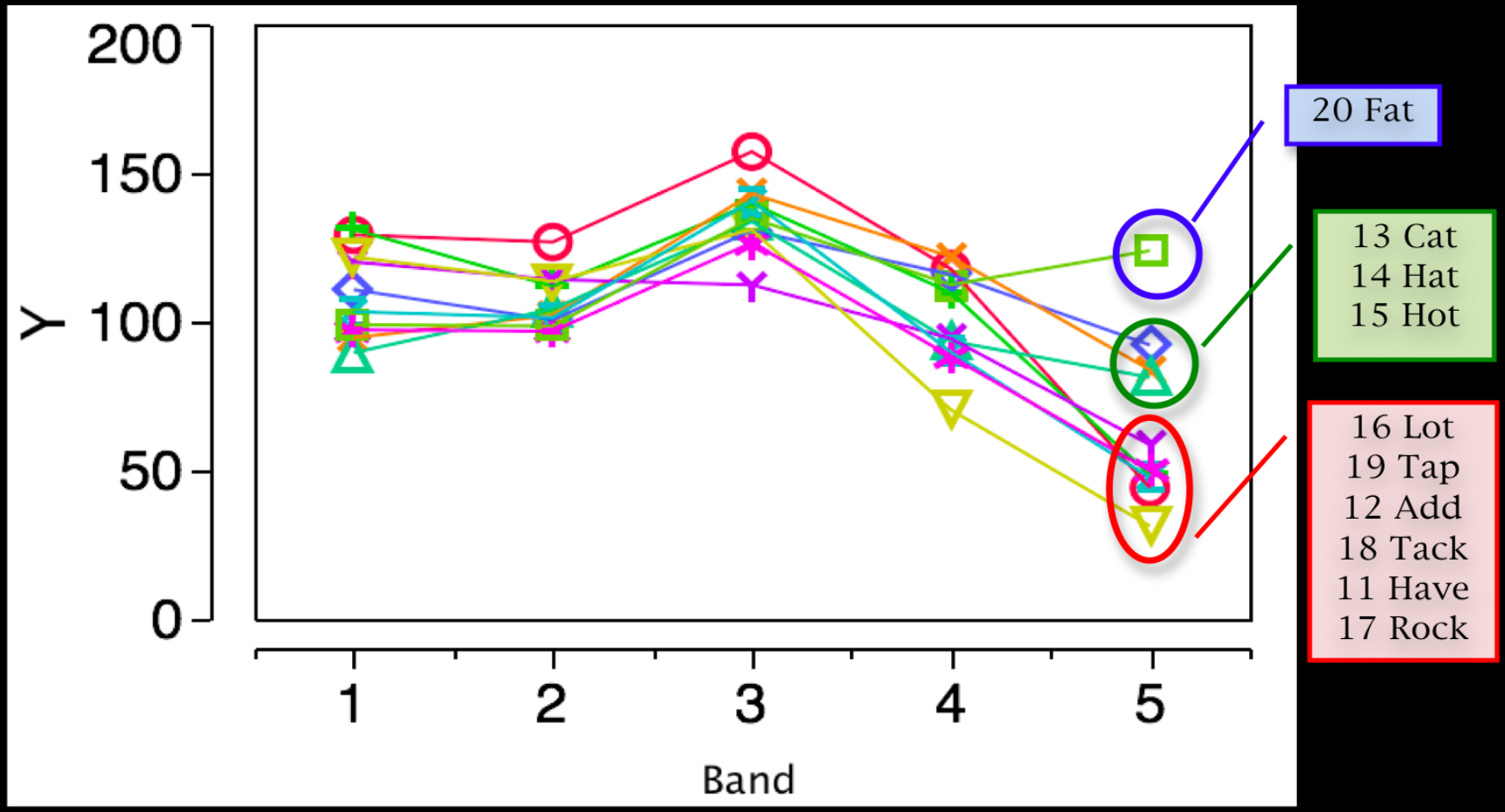
Evaluating the Energy Information at Each Frequency – The Word Cease



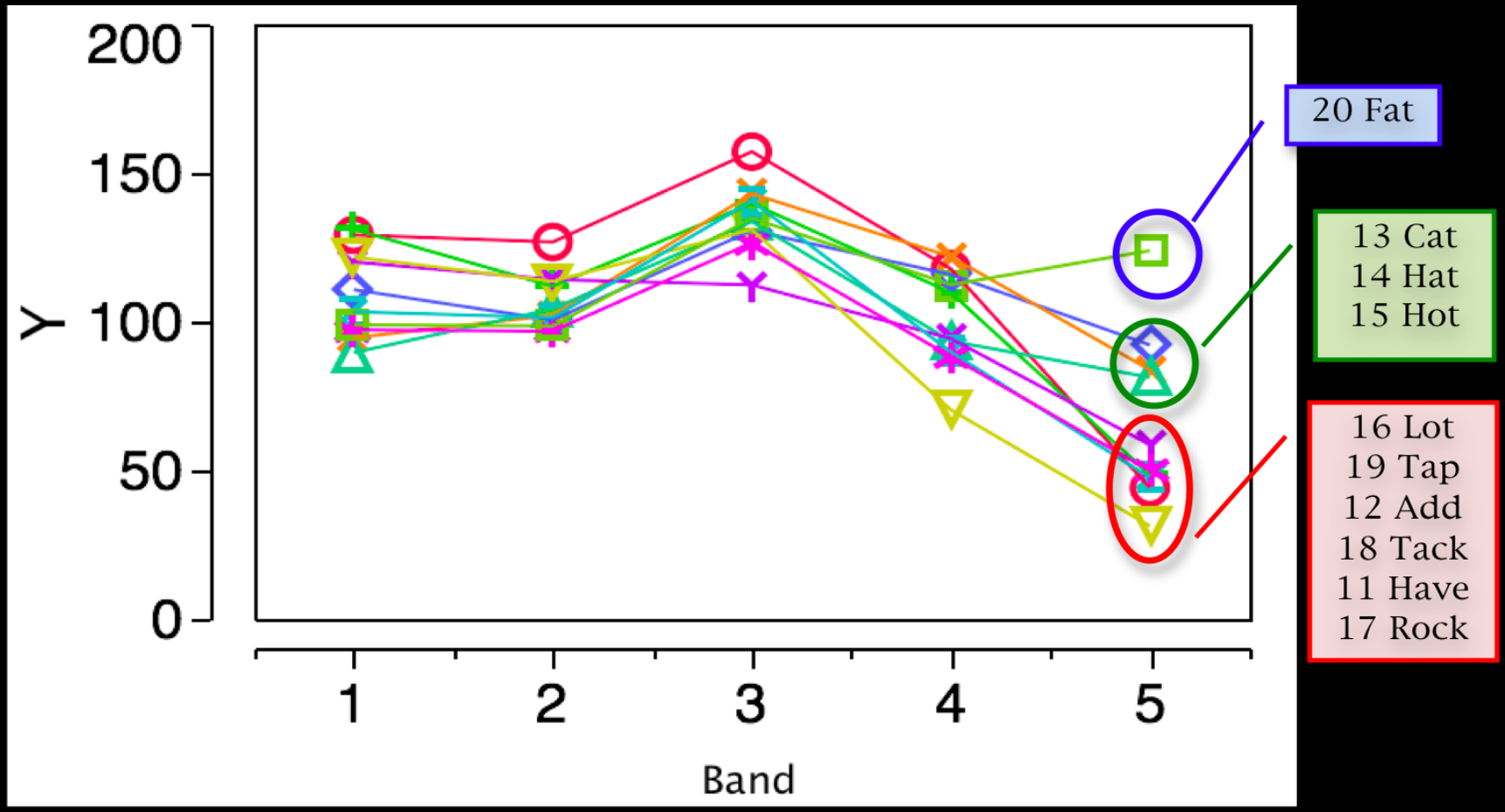
Low Frequency Words



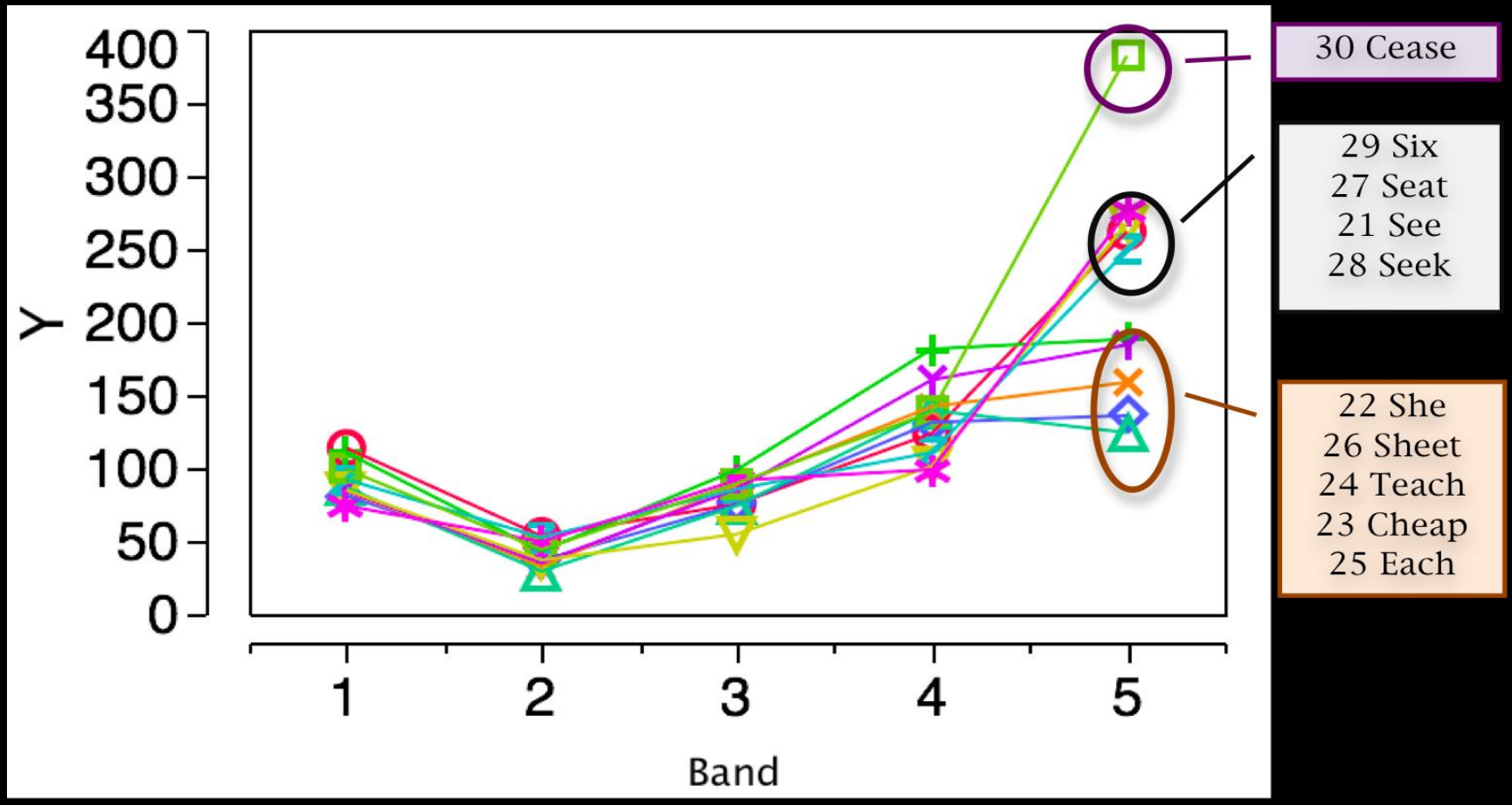
Mid Frequency Words



Mid Frequency Words



High Frequency Words



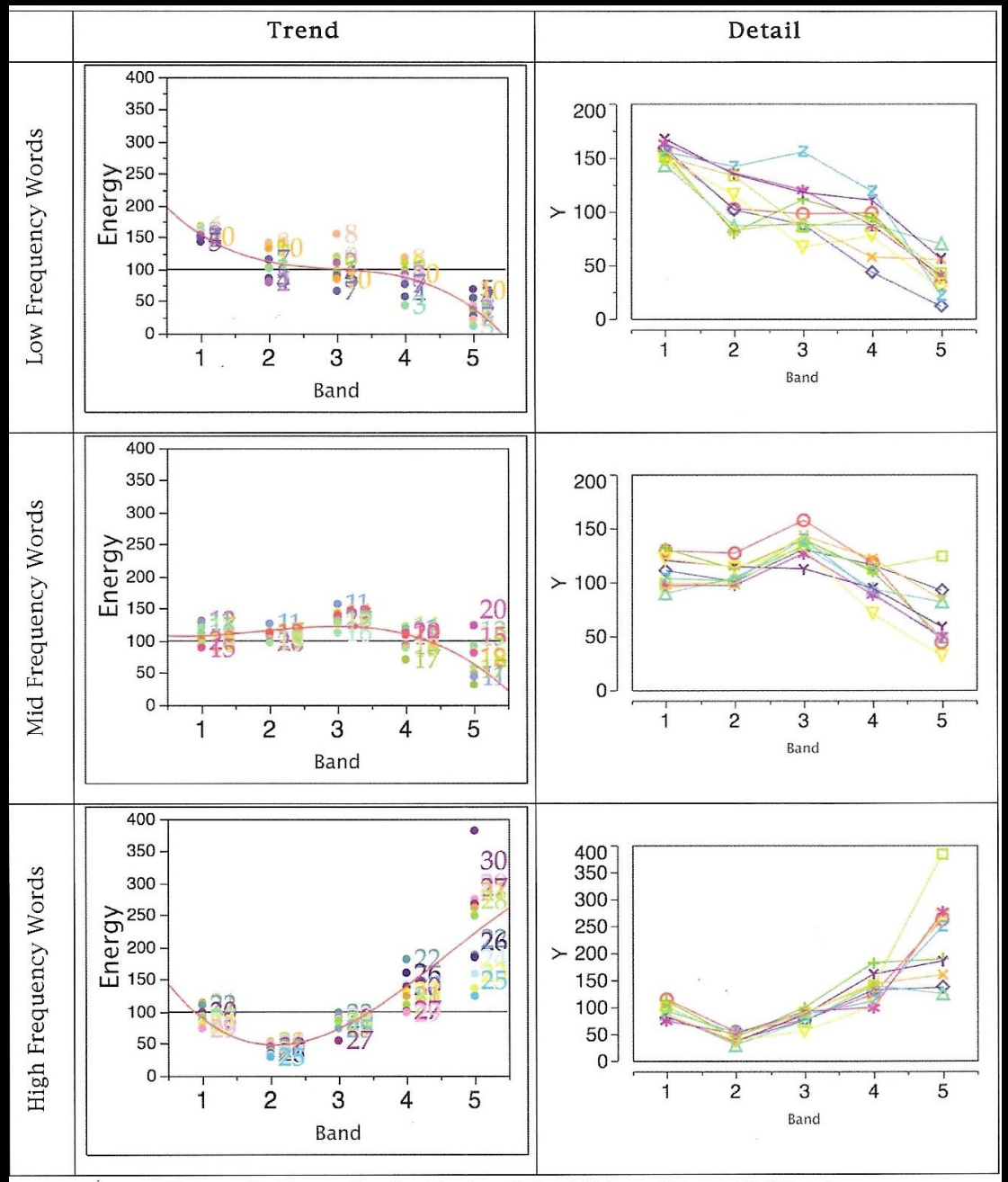
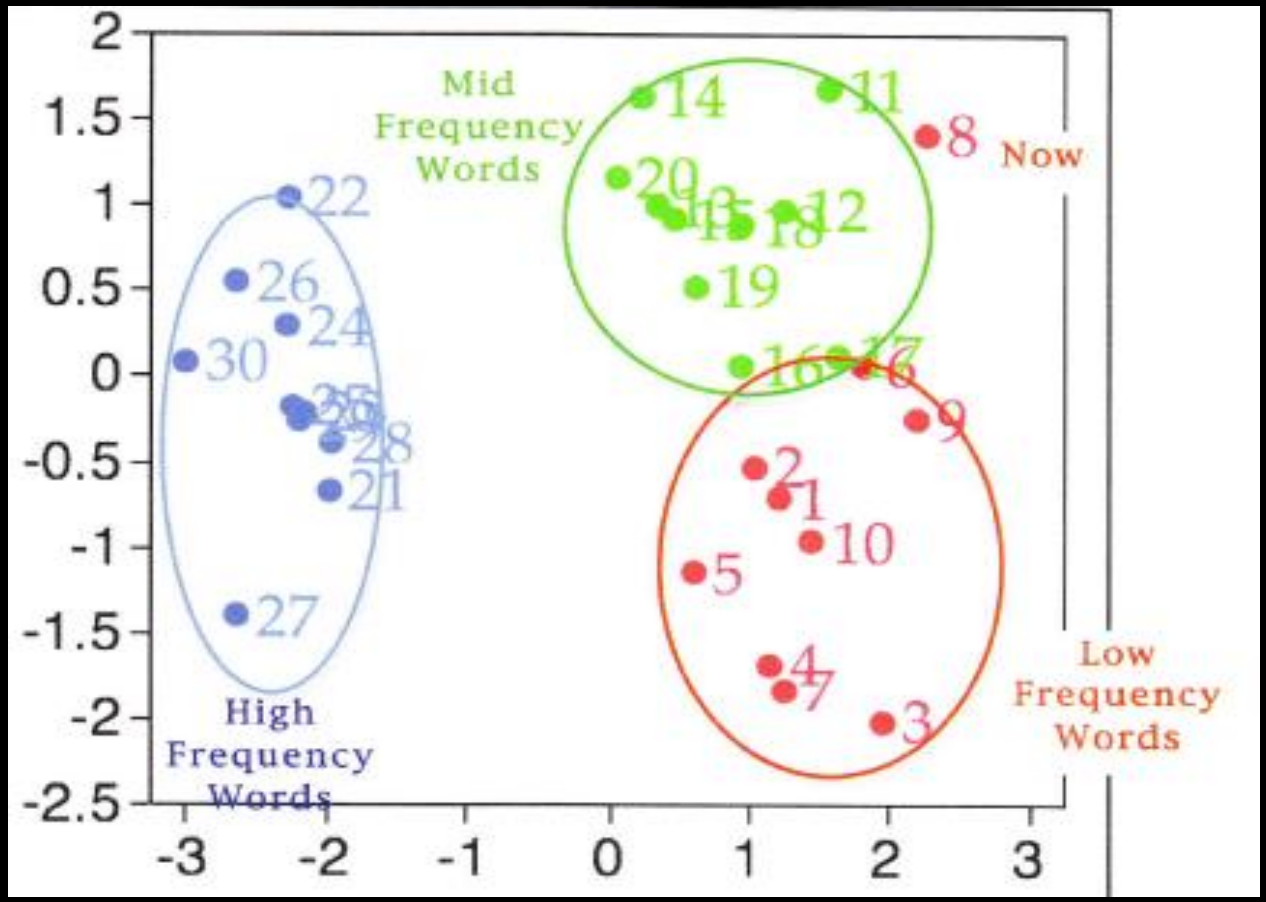


Figure 3: Energies in Each of the Thirty "Bessel" Words

Plot Showing the Clustering of the 30 Frequency-balanced (Tonality) Words

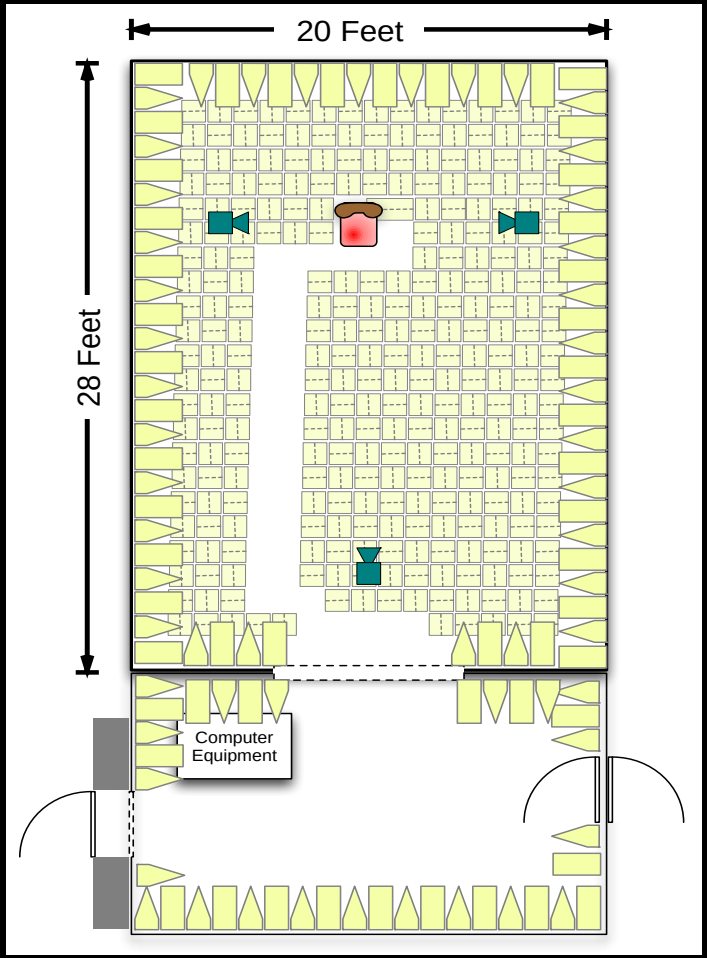


Perceived Ranking (Bessel 1979)

Low			Mid			High	
1	Blue		11	Have		21	See
2	New		12	Add		22	She
3	Room		13	Cat		23	Cheap
4	Move		14	Hat		24	Teach
5	Wood		15	Hot		25	Each
6	No		16	Lot		26	Sheet
7	Bone		17	Rock		27	Seat
8	Now		18	Tack		28	Seek
9	Row		19	Tap		29	Six
10	Bow		20	Fat		30	Cease

Determining Energy in Words

- Professionally recorded words presented through an electronic speaker.
- Low noise environment (Anechoic Chamber)
- Recorded on two microphones:
  - a high quality microphone above a patients head
  - A modified hearing aid microphone in the ear canal of a patient.



Microphones (Agreement < 2 dB)

Reference

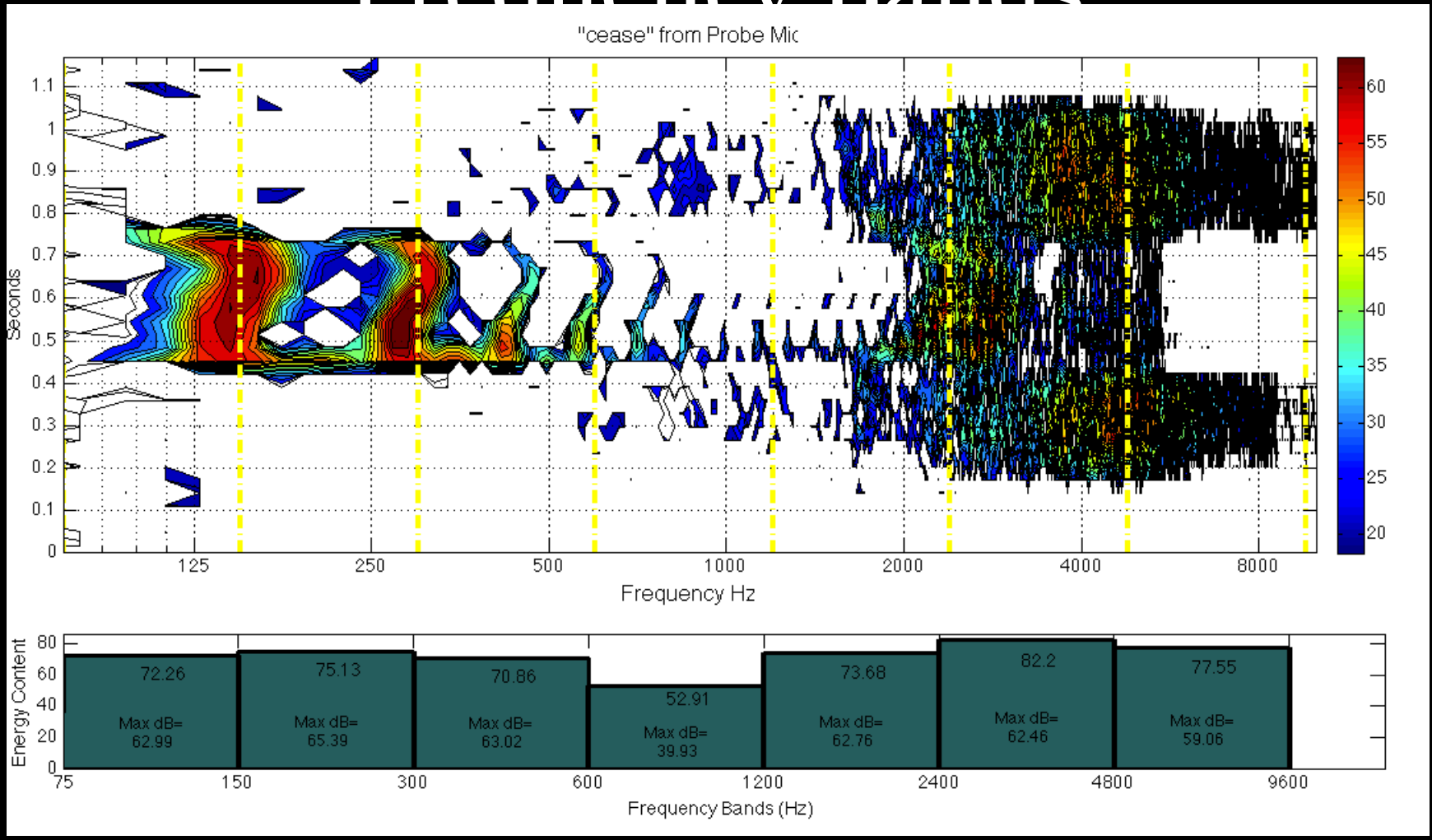
- High quality microphone from B&K.
- Microphone positioned directly over patients head.

Probe

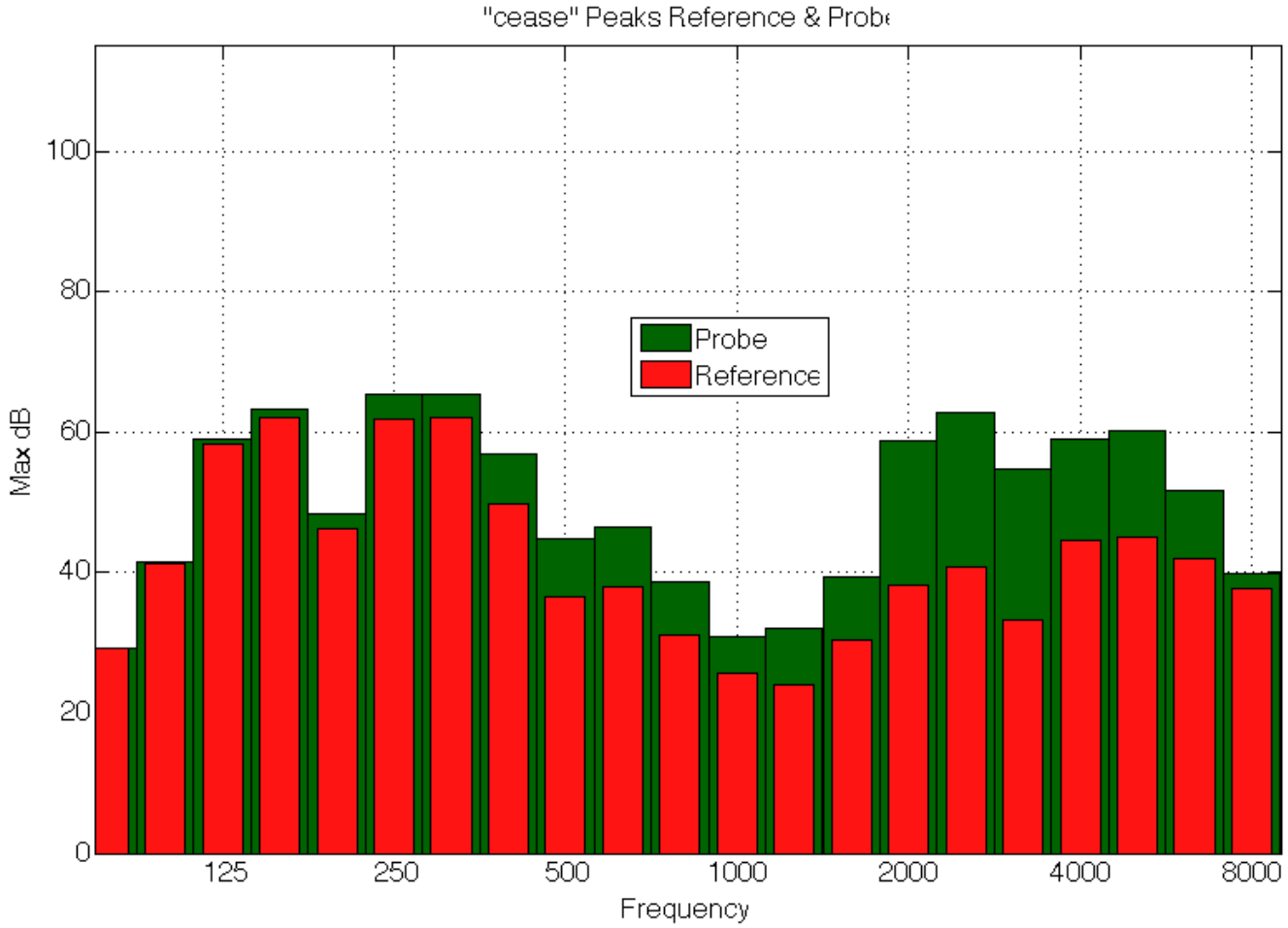
- Accurate measurements for signals over 25 dB and less than 8000 Hz.
- Converted hearing aid microphone.

Having the multiple recordings allows us a clear picture of how the energy in that particular speech signal is amplified by the resonance of the ear canal

Summarizing the Energy in Frequency Bands



Comparison with Probe Microphone Inside the Ear



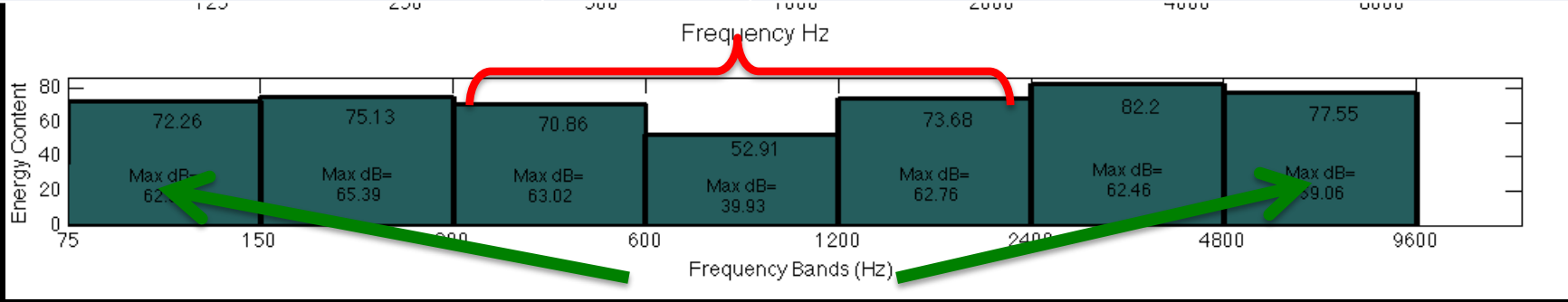
Examples – Blue – Hot – Cease (On Probe)

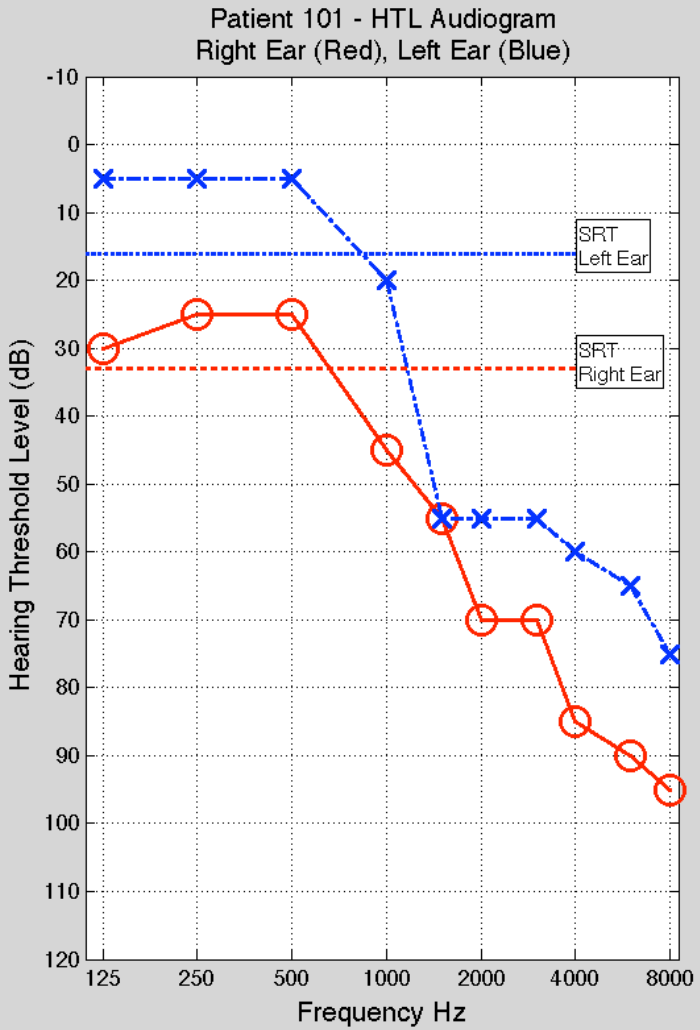
Agreement Between Energy Distribution and Perceived Pitch

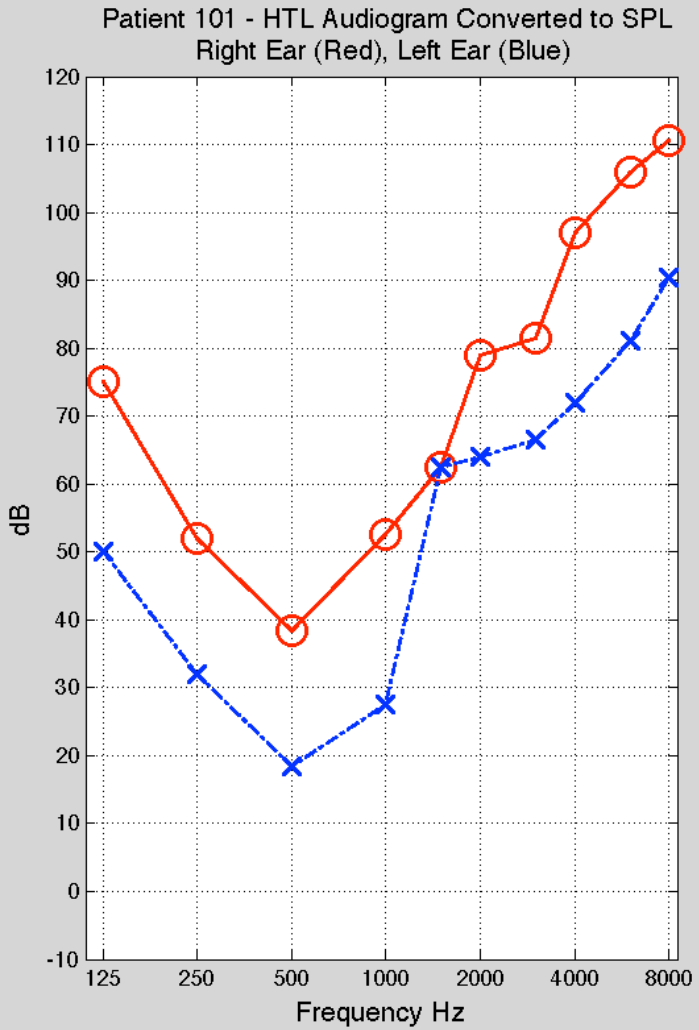
- Multiple Linear Regression
  - The statistical technique used to assess whether an outcome can be predicted from a set of measured variables.
    - i.e., Does the energy in each frequency band predict the perceived pitch ranking.
  - The strength of that relationship is measured by the statistic R^2, which is:
    - between zero,
      - i.e. no correlation and
    - 100%.
      - i.e., perfect agreement

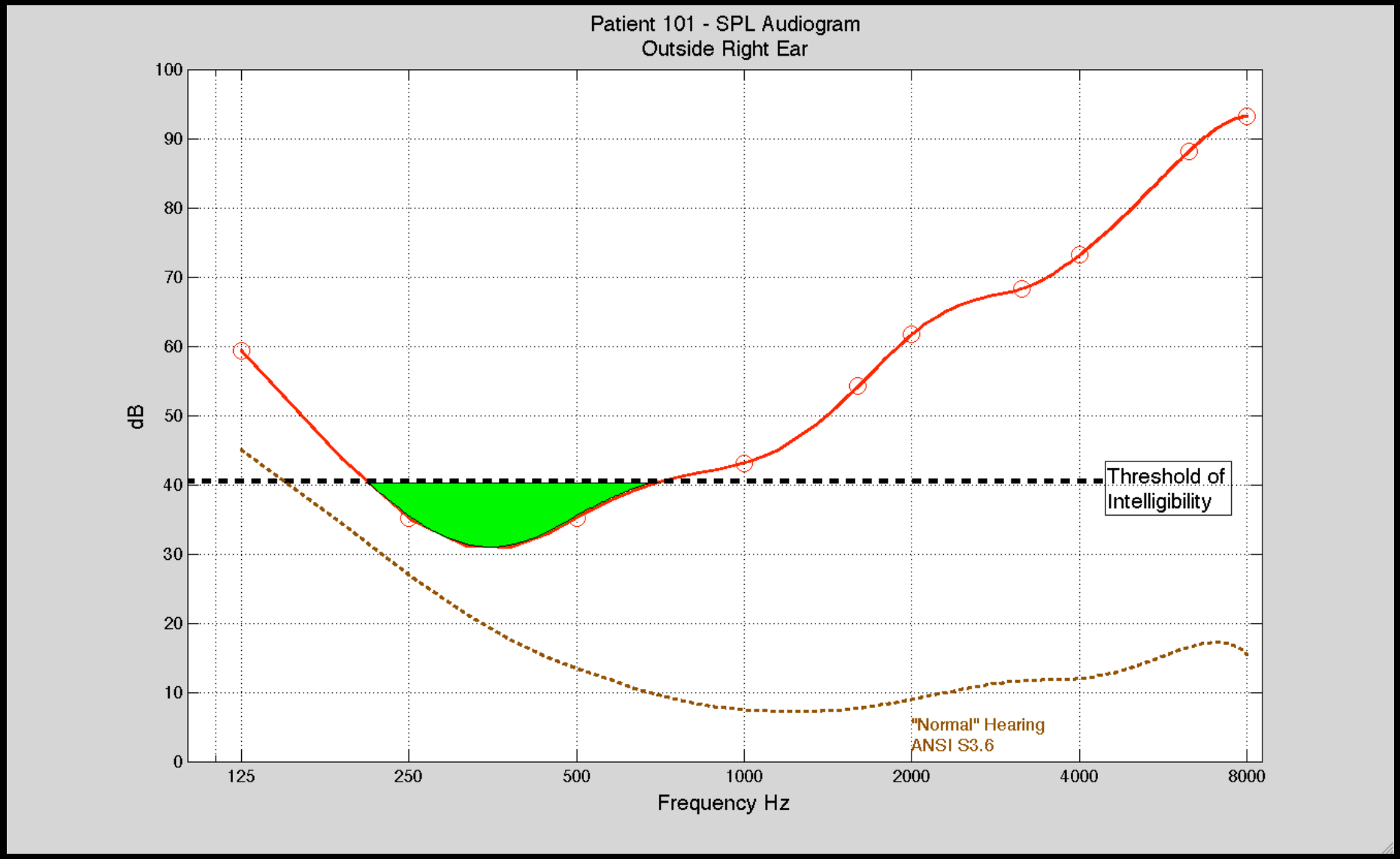
Regression Results on Information Required to Predict

Predictors	R^2	Comments
All bands measured ***outside*** the ear.	96%	
All bands measured ***inside*** the ear canal.	97%	The best set of predictors.
Just the extreme bands (<150Hz &>4800 Hz)	89%	These discontinuous bands provide lots of information! Even helps a patient rank the pitch of mid frequency words!
The bands between 500Hz and 2400 Hz	70%	Most people accurately understand all the words with just 70% of the information. (These are the bands passed by the telephone).

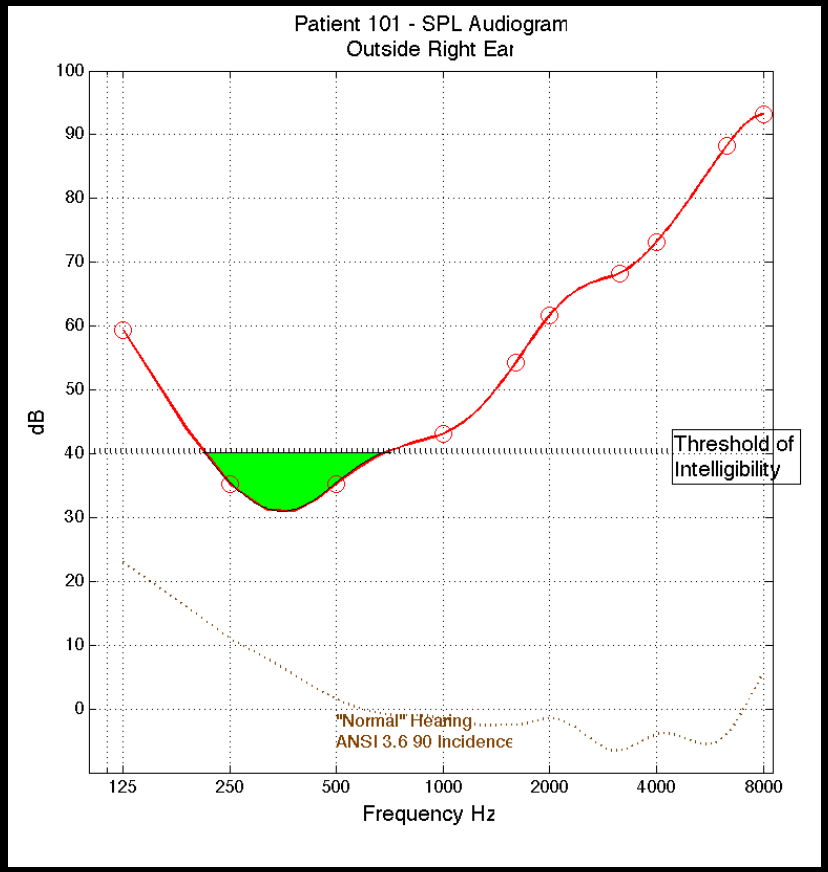


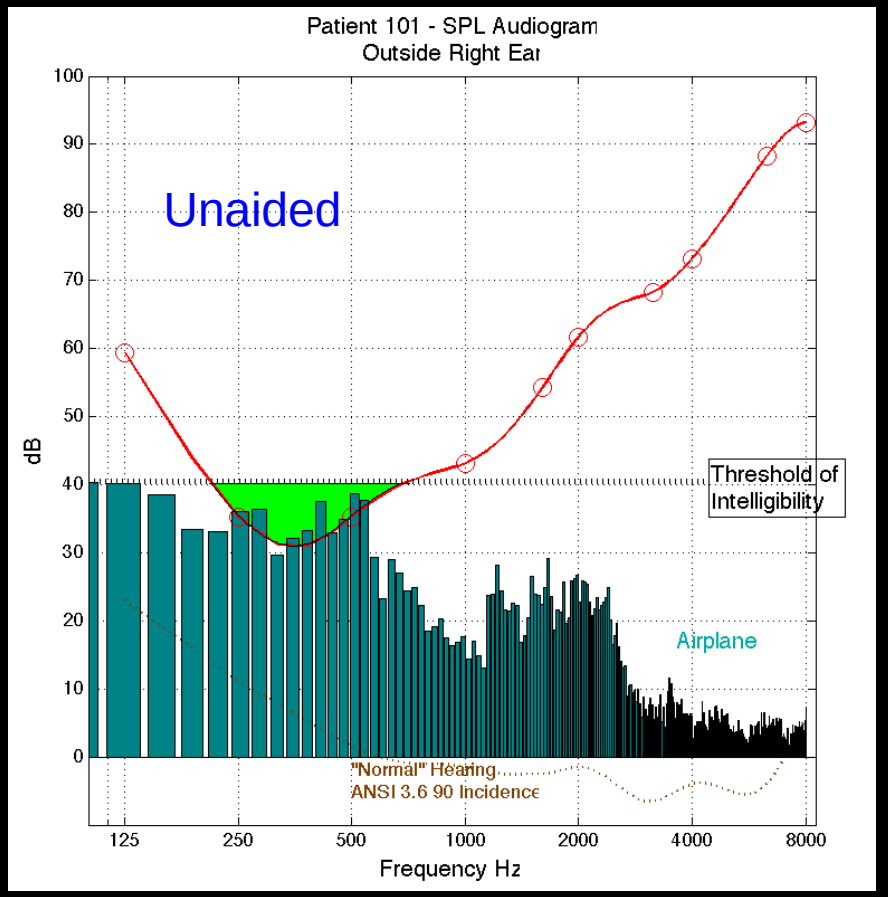

Patient 101 - HTL Audiogram
Right Ear (Red), Left Ear (Blue)
Hearing Threshold Level (dB)
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
SRT
Left Ear
SRT
Right Ear
125
250
500
1000
2000
4000
8000
Frequency Hz


Patient 101 - HTL Audiogram Converted to SPL
Right Ear (Red), Left Ear (Blue)
dB
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
125
250
500
1000
2000
4000
8000
Frequency Hz


Patient 101 - SPL Audiogram
Outside Right Ear
dB
Frequency Hz
100
90
80
70
60
50
40
30
20
10
0
125
250
500
1000
2000
4000
8000
Threshold of Intelligibility
"Normal" Hearing
ANSI S3.6

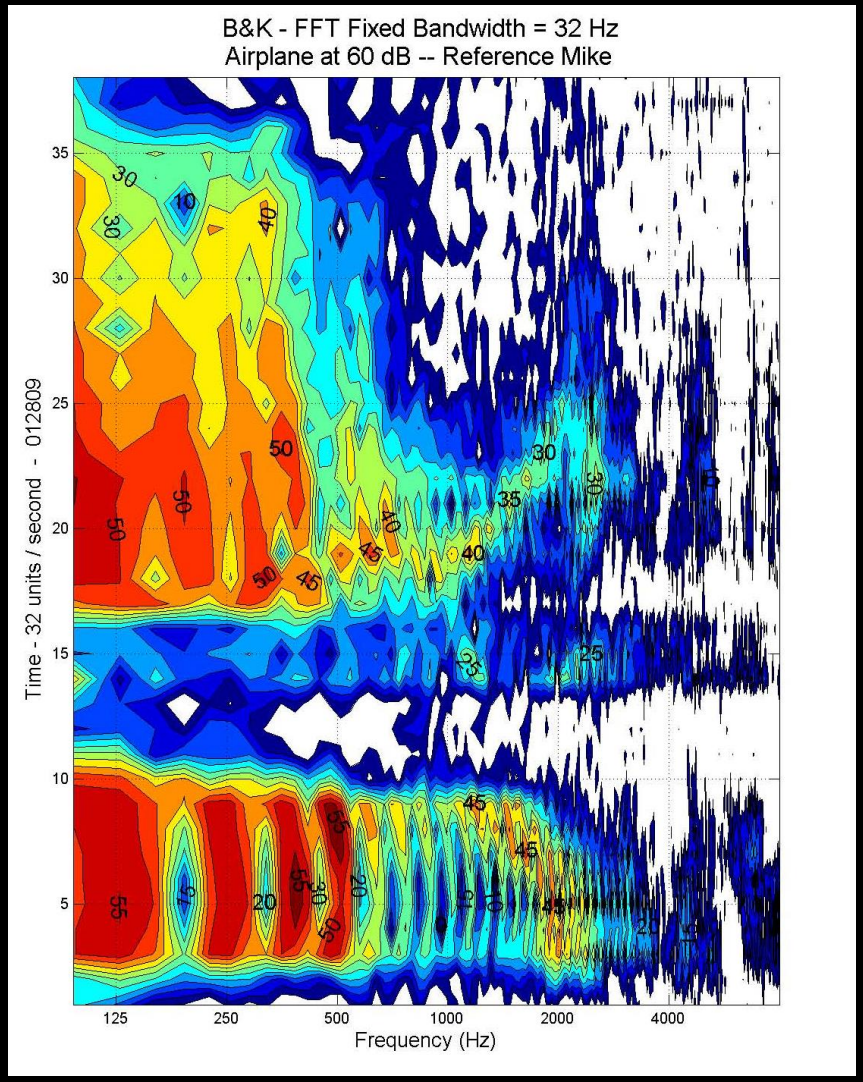
Word Accurately Perceived by the Patient

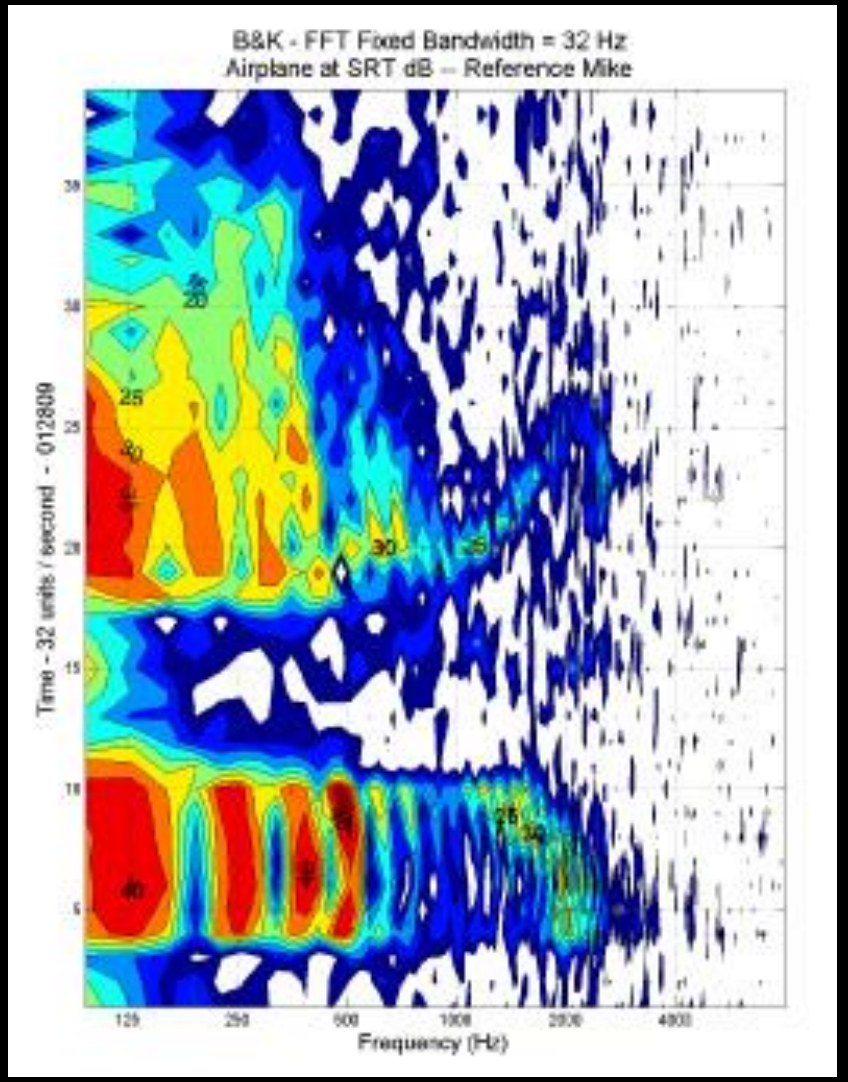




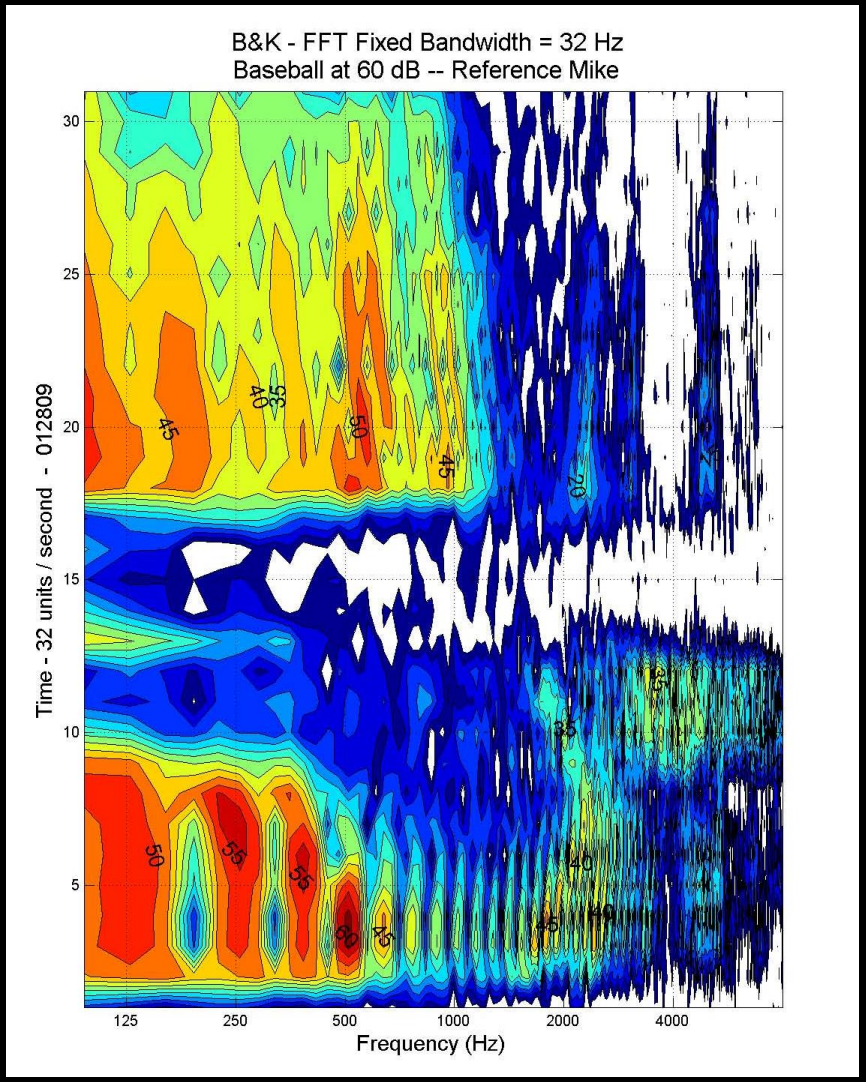
What information needs to be available to the patient in order to decode speech?

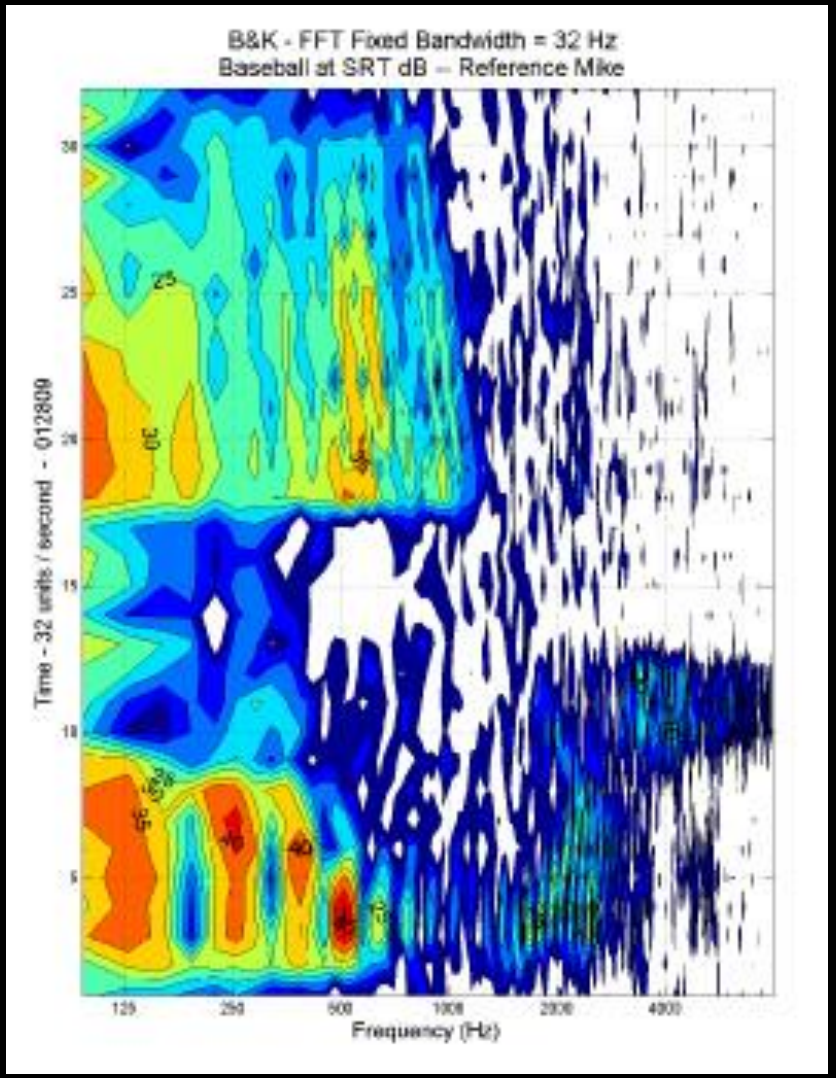
Airplane at 60 dB and SRT



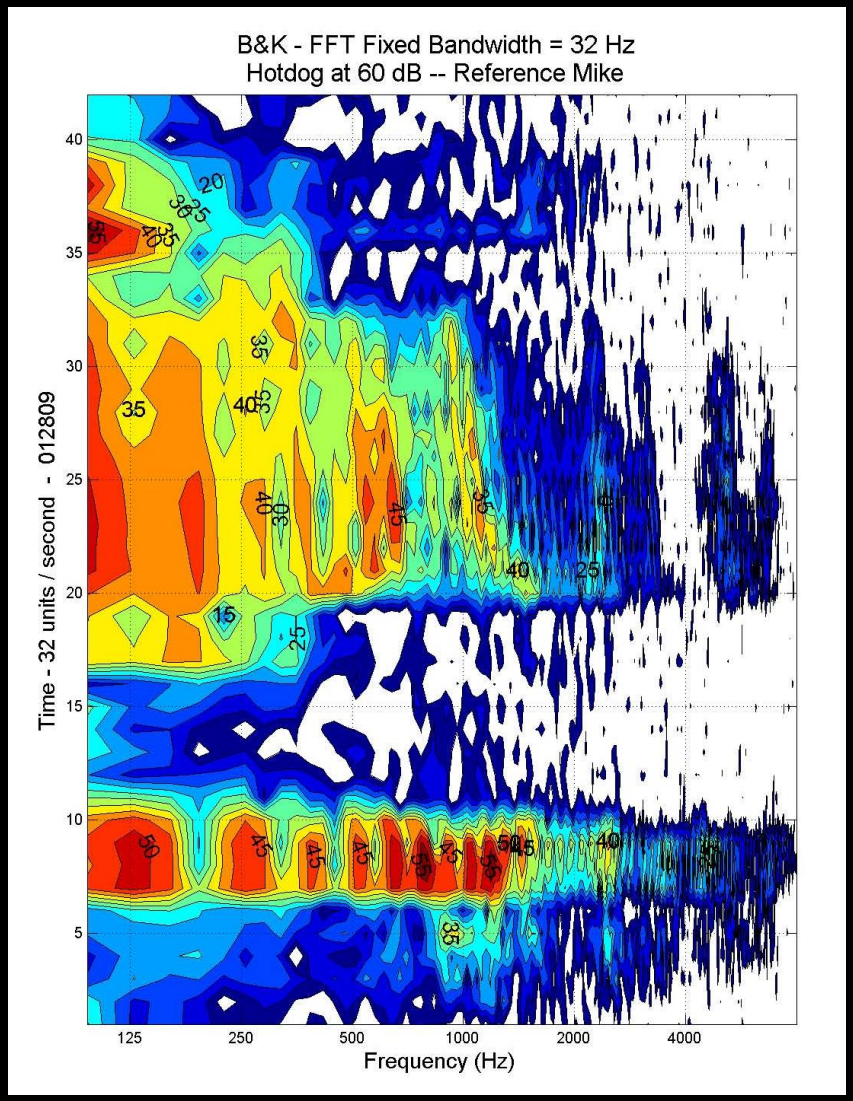


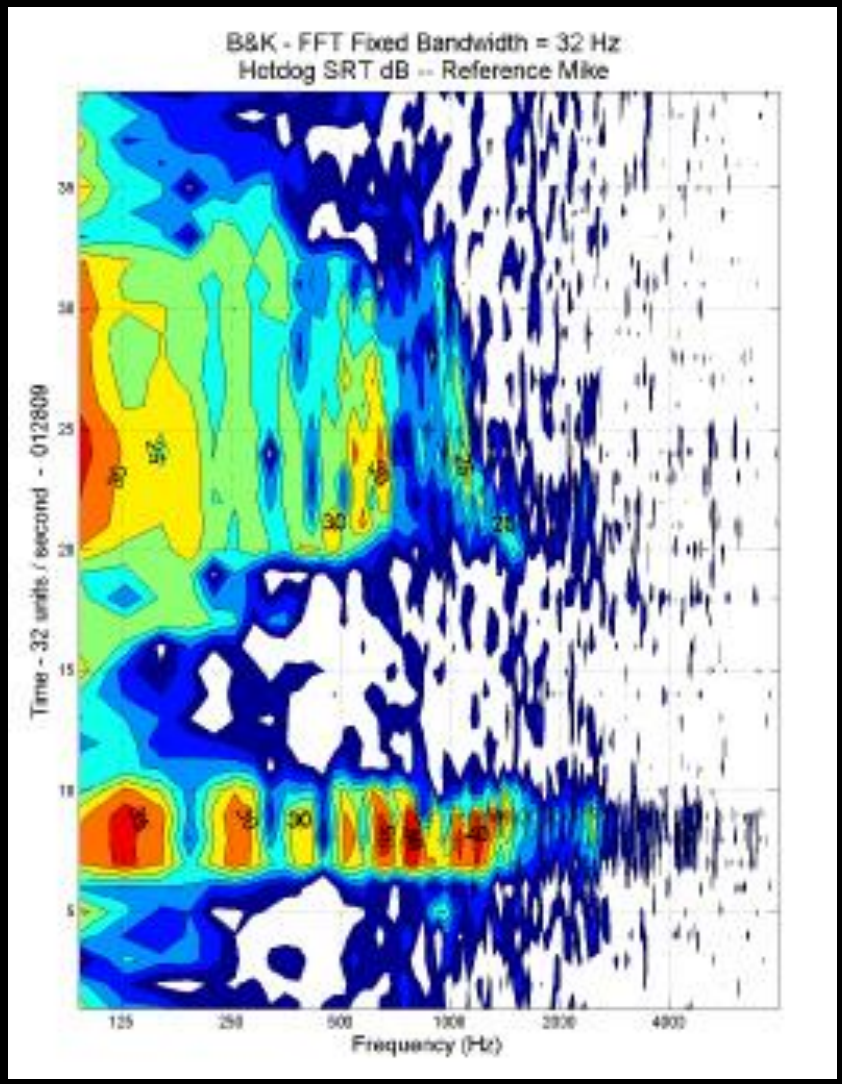
Baseball at 60 dB and SRT



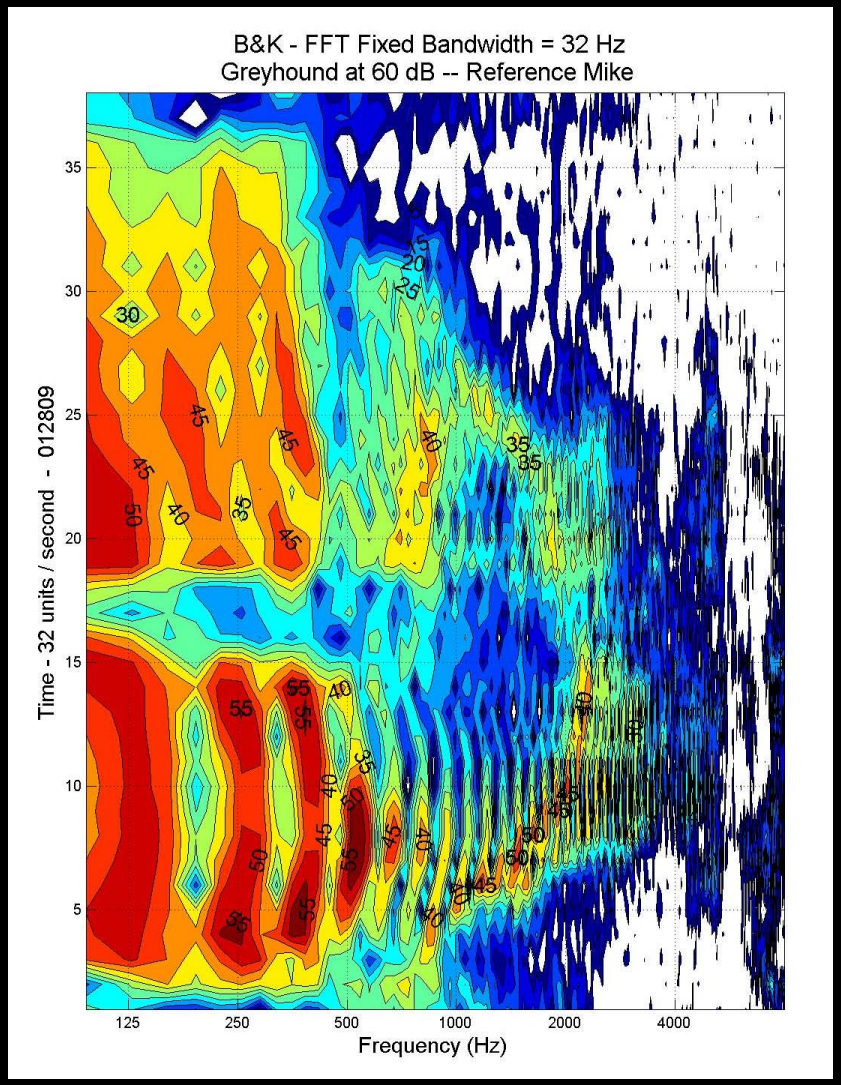


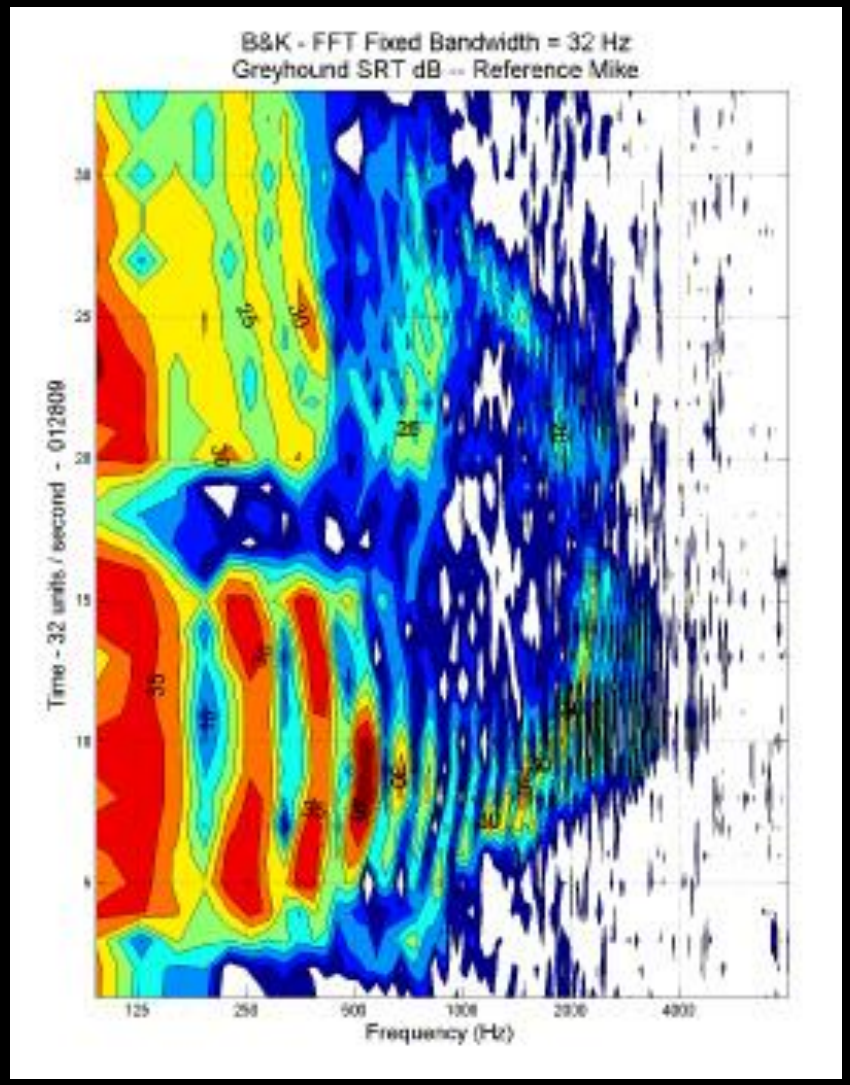
Hotdog at 60 dB and SRT



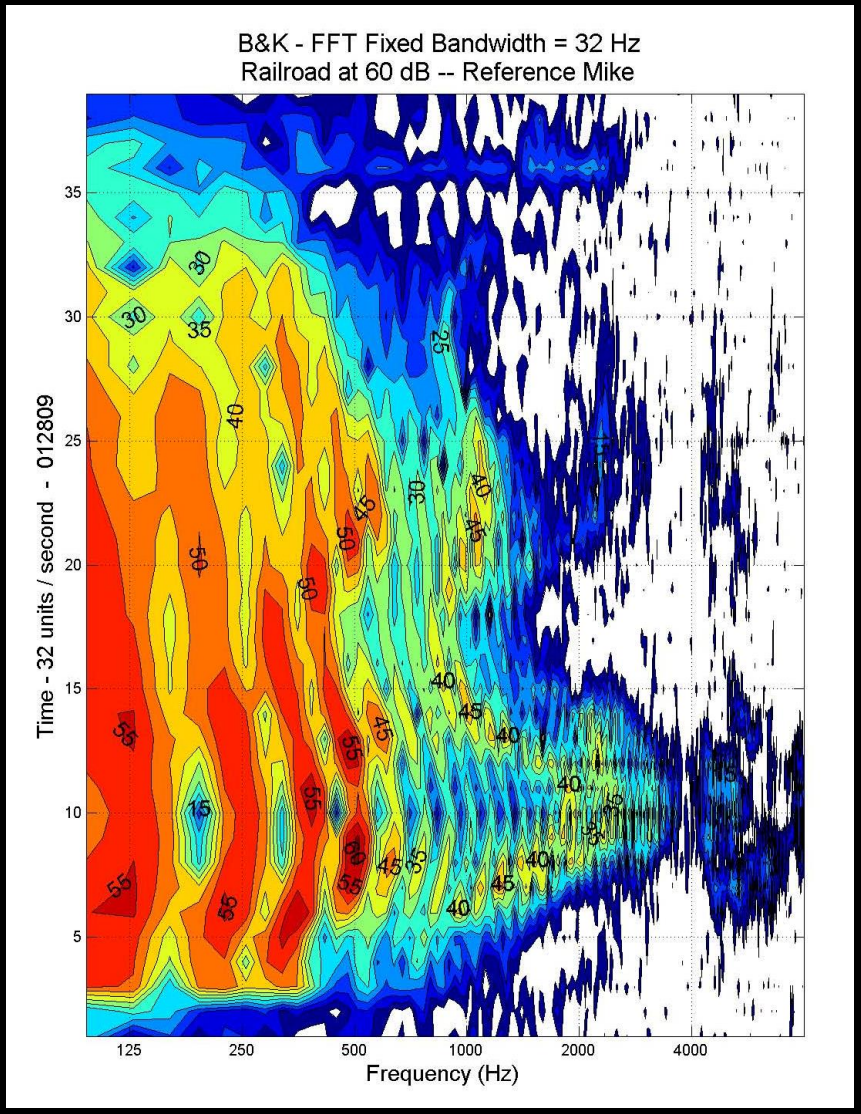


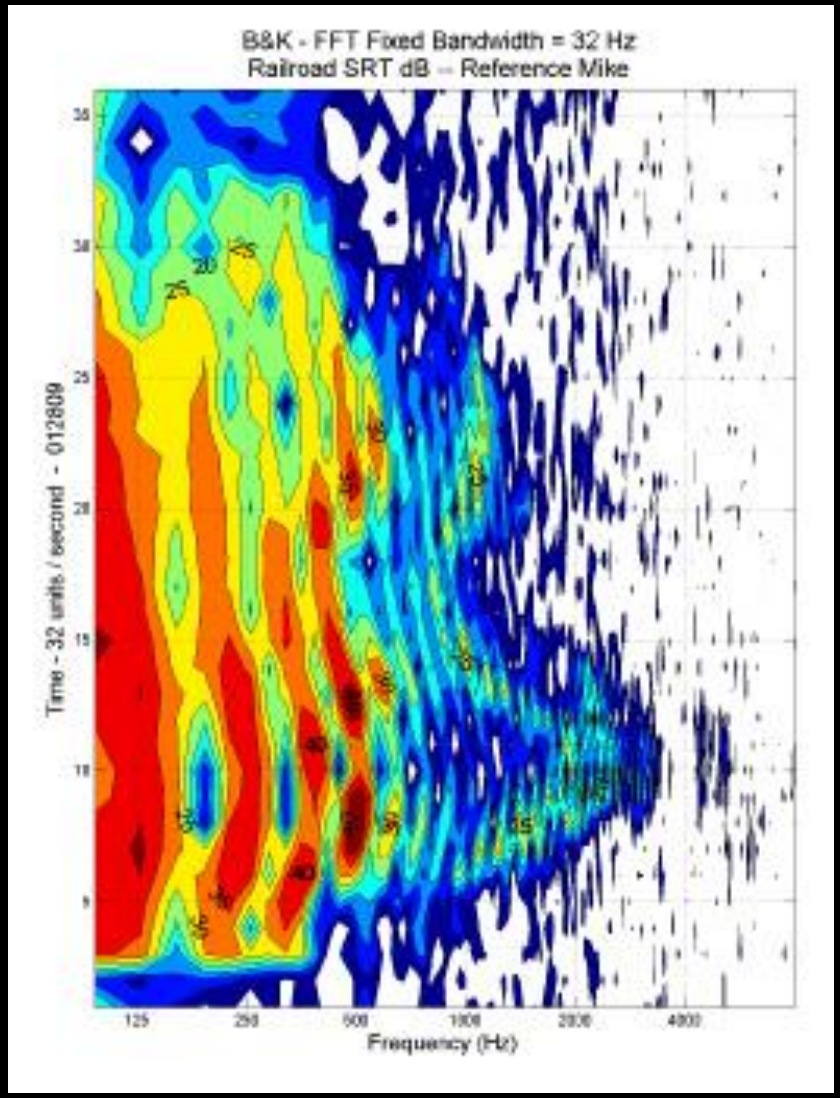
Greyhound at 60 dB and SRT



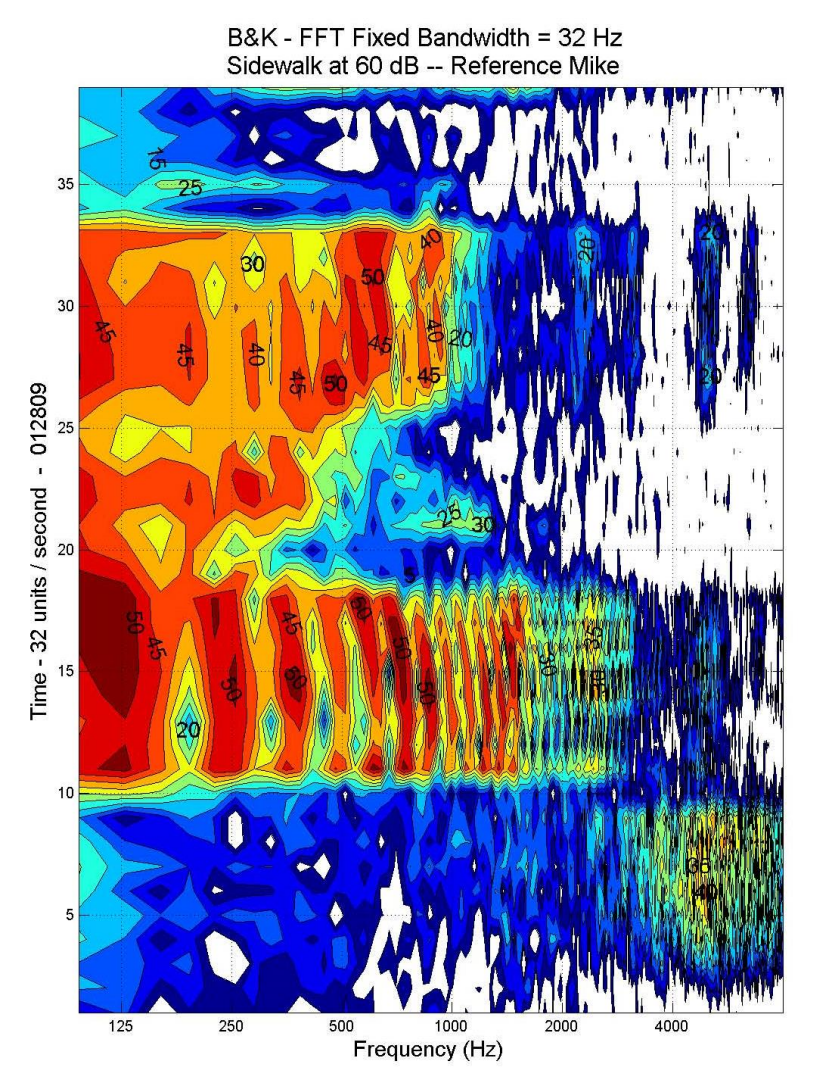


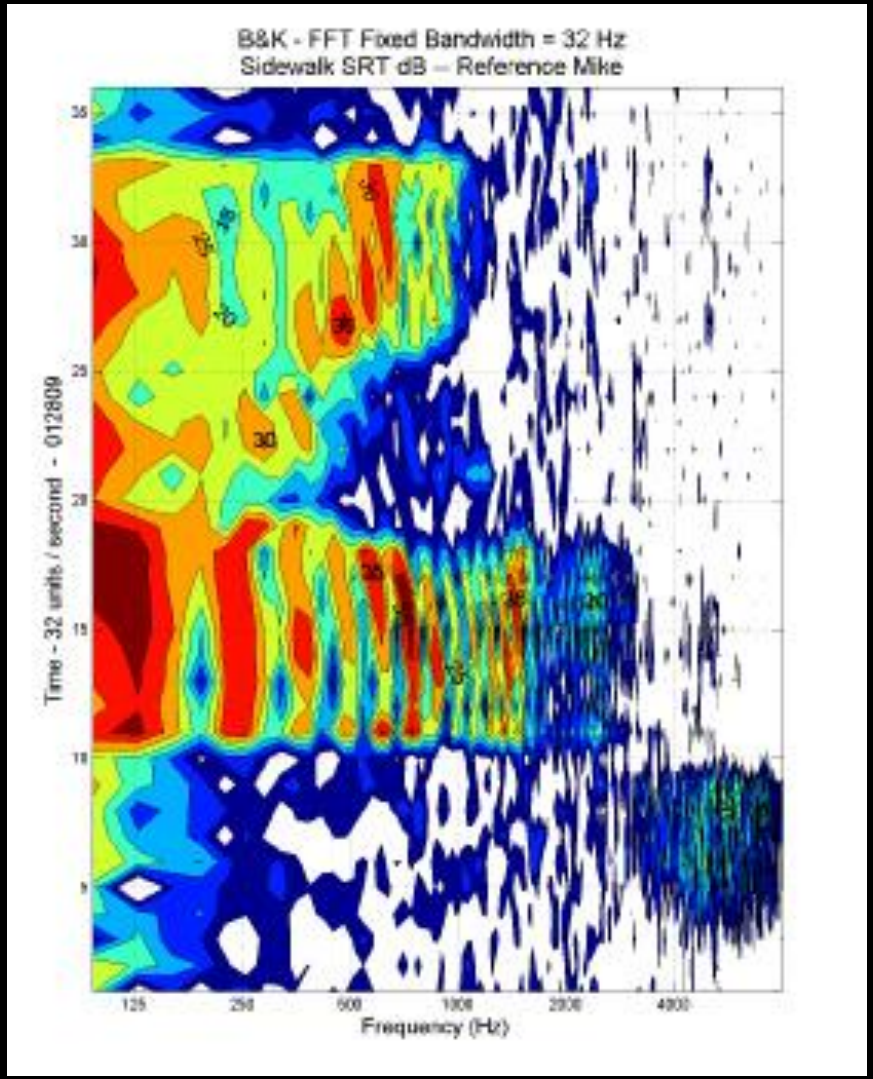
Railroad at 60 dB and SRT

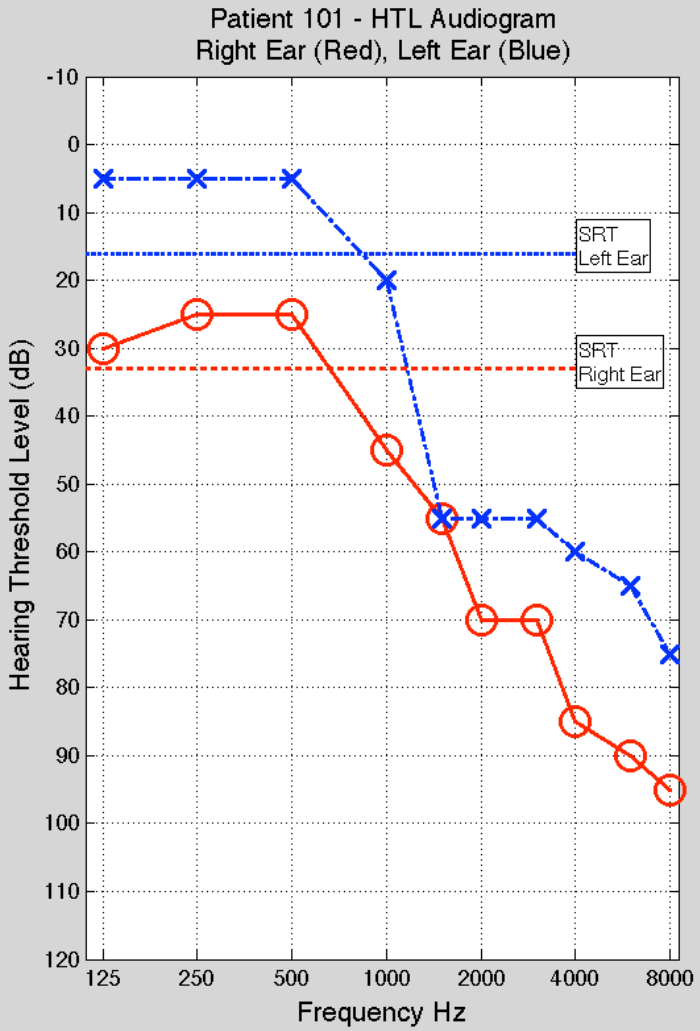


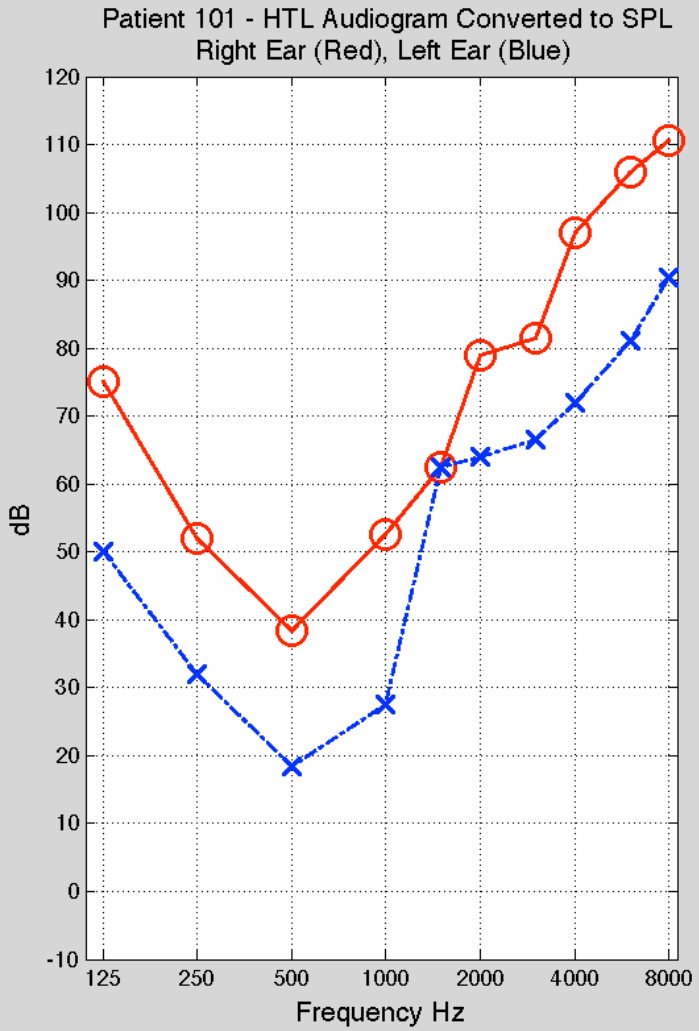


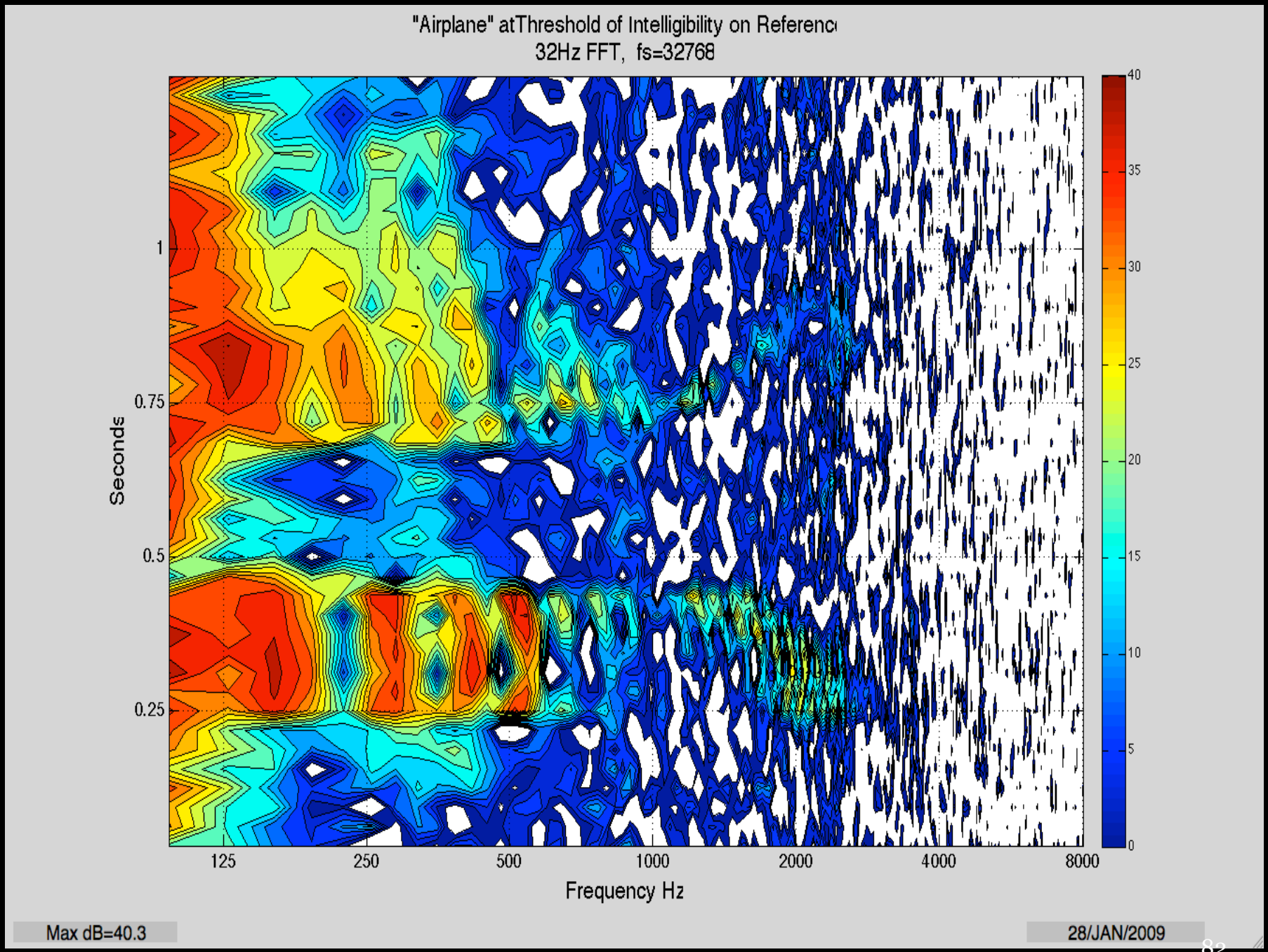
Sidewalk at 60 dB and SRT

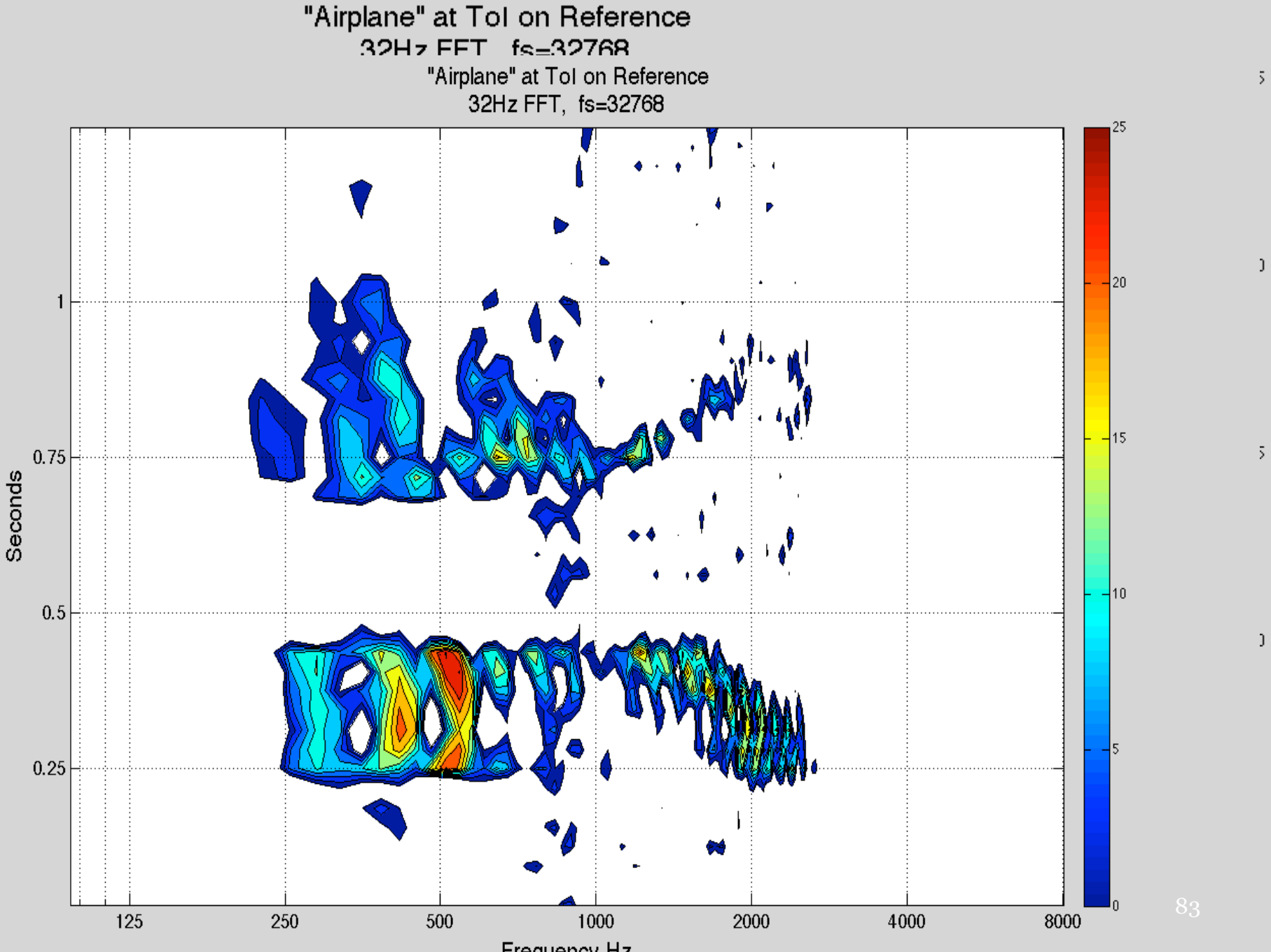


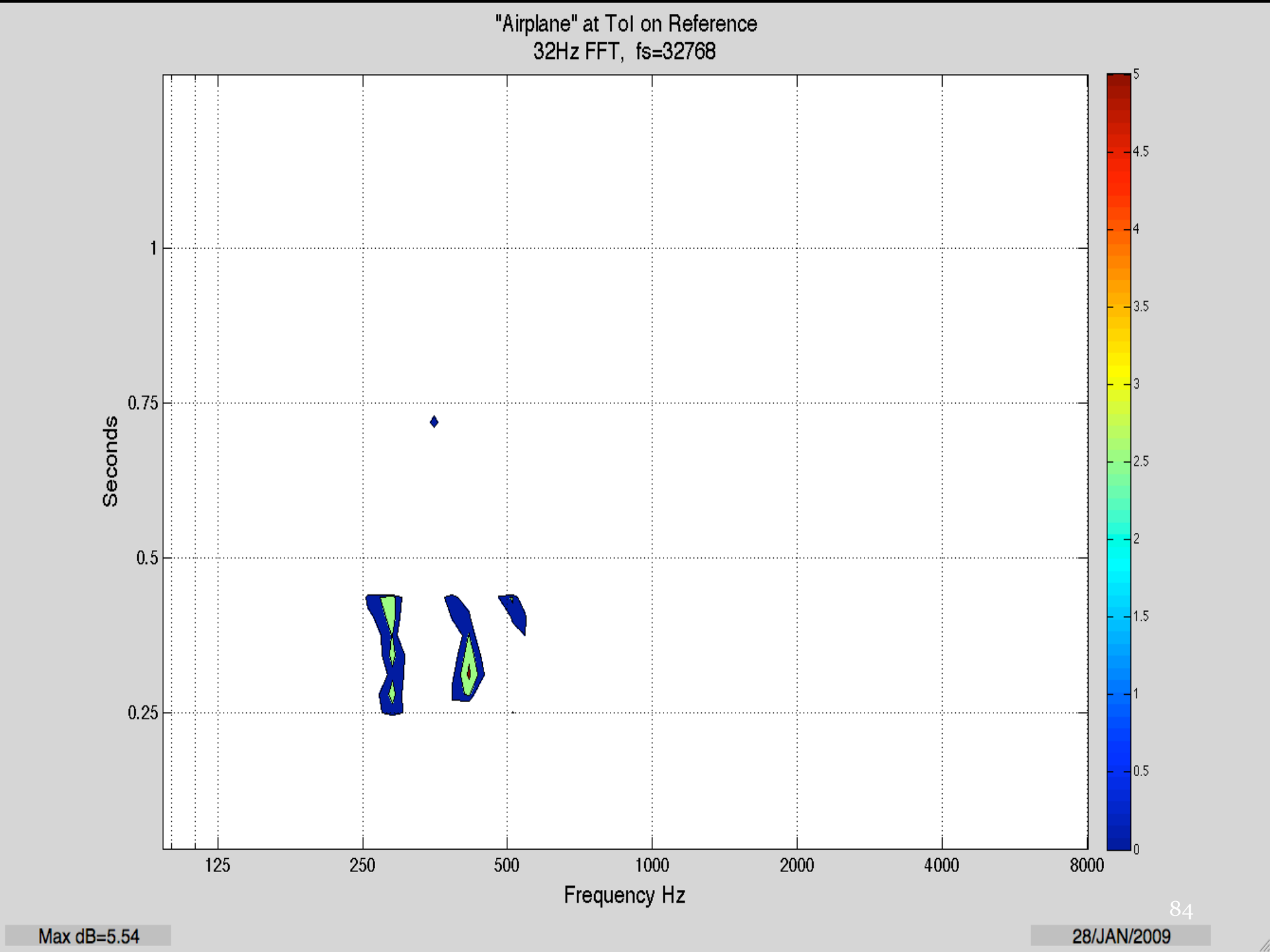



Patient 101 - HTL Audiogram
Right Ear (Red), Left Ear (Blue)
Hearing Threshold Level (dB)
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
SRT
Left Ear
SRT
Right Ear
125
250
500
1000
2000
4000
8000
Frequency Hz


Patient 101 - HTL Audiogram Converted to SPL
Right Ear (Red), Left Ear (Blue)
dB
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
125
250
500
1000
2000
4000
8000
Frequency Hz

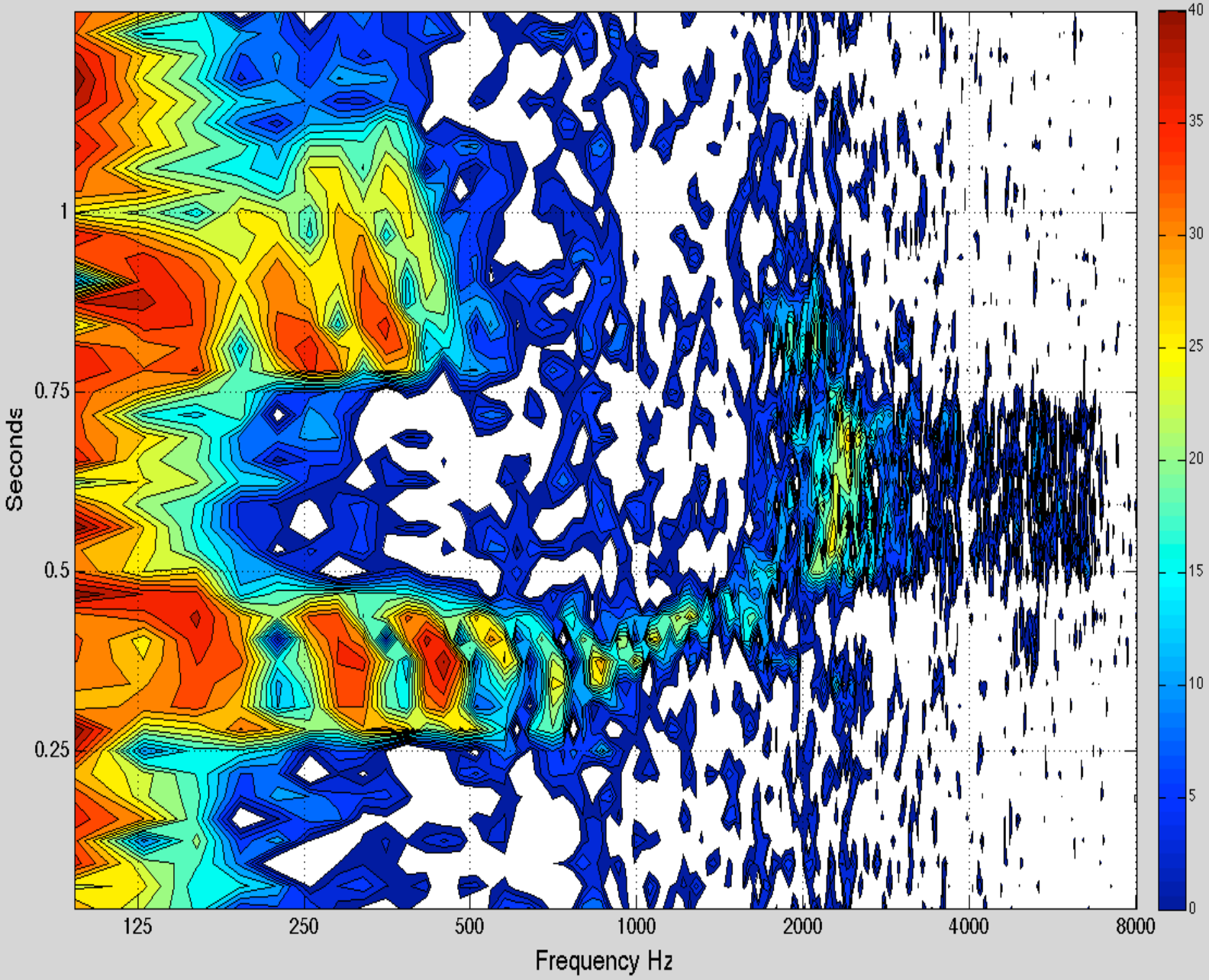

"Airplane" atThreshold of Intelligibility on Referenc
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
Frequency Hz
40
35
30
25
20
15
10
5
0
Max dB=40.3
28/JAN/2009


"Airplane" at ToI on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
25
20
15
10
5
0



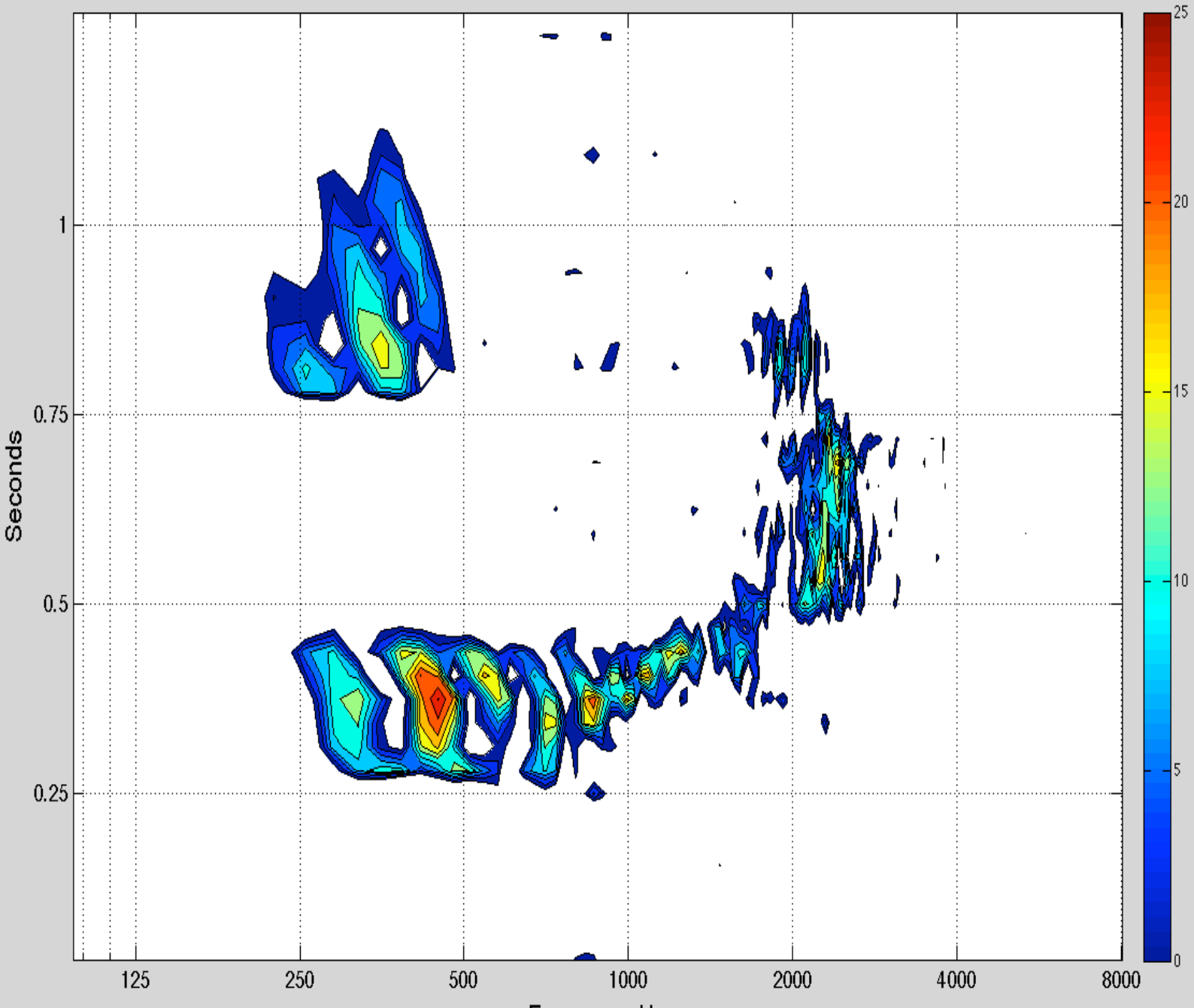
Max dB=5.54

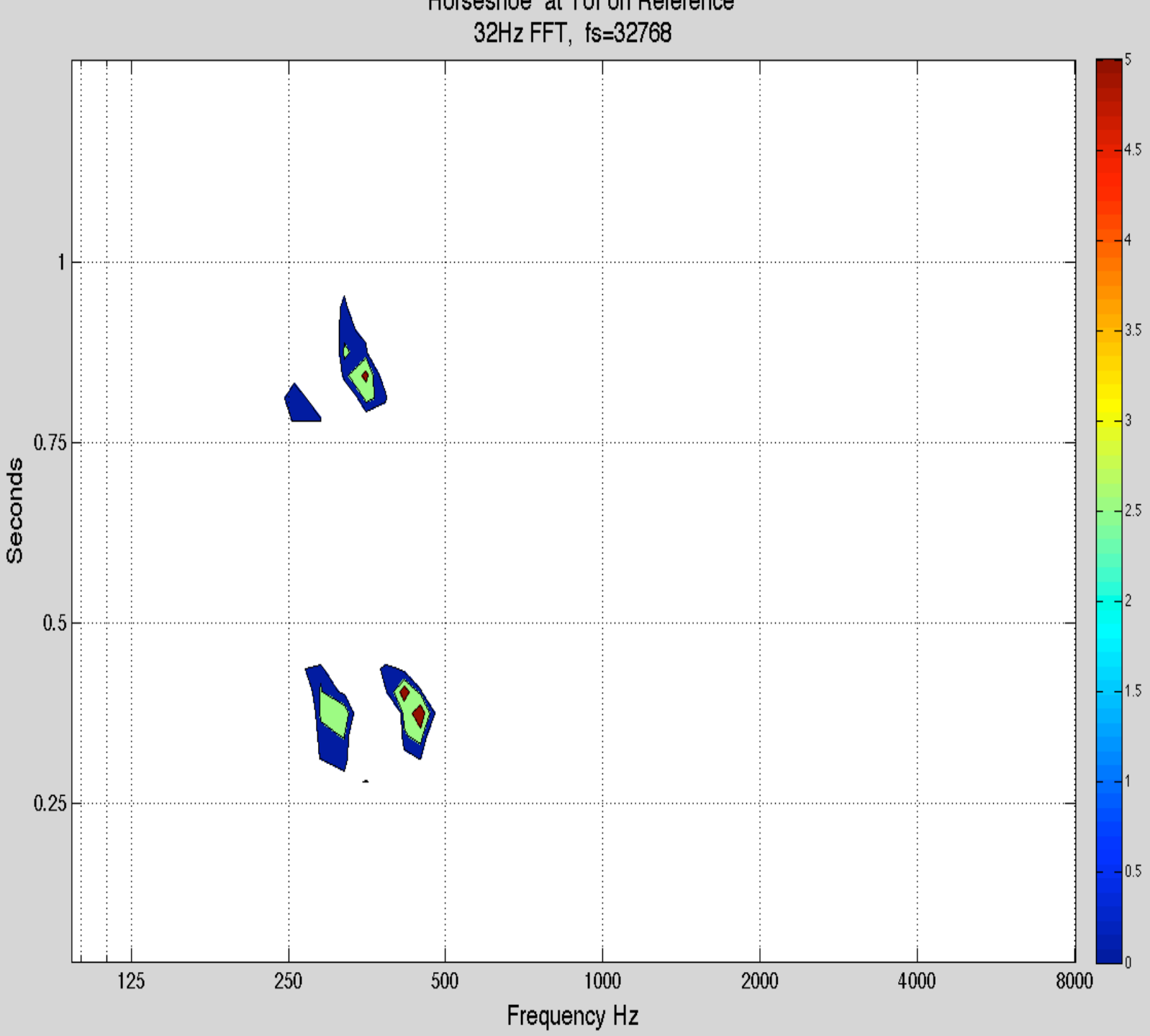
28/JAN/2009

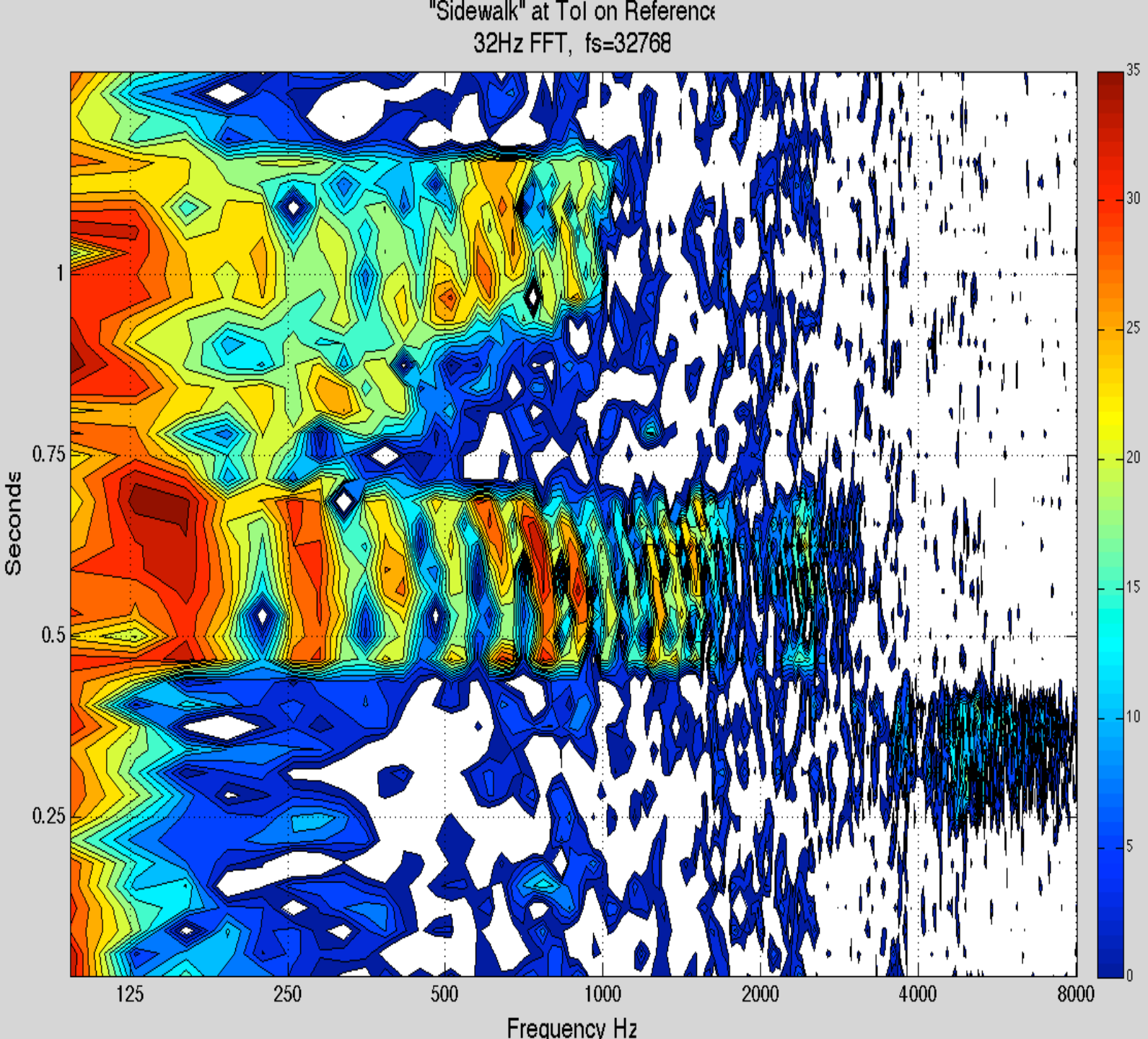


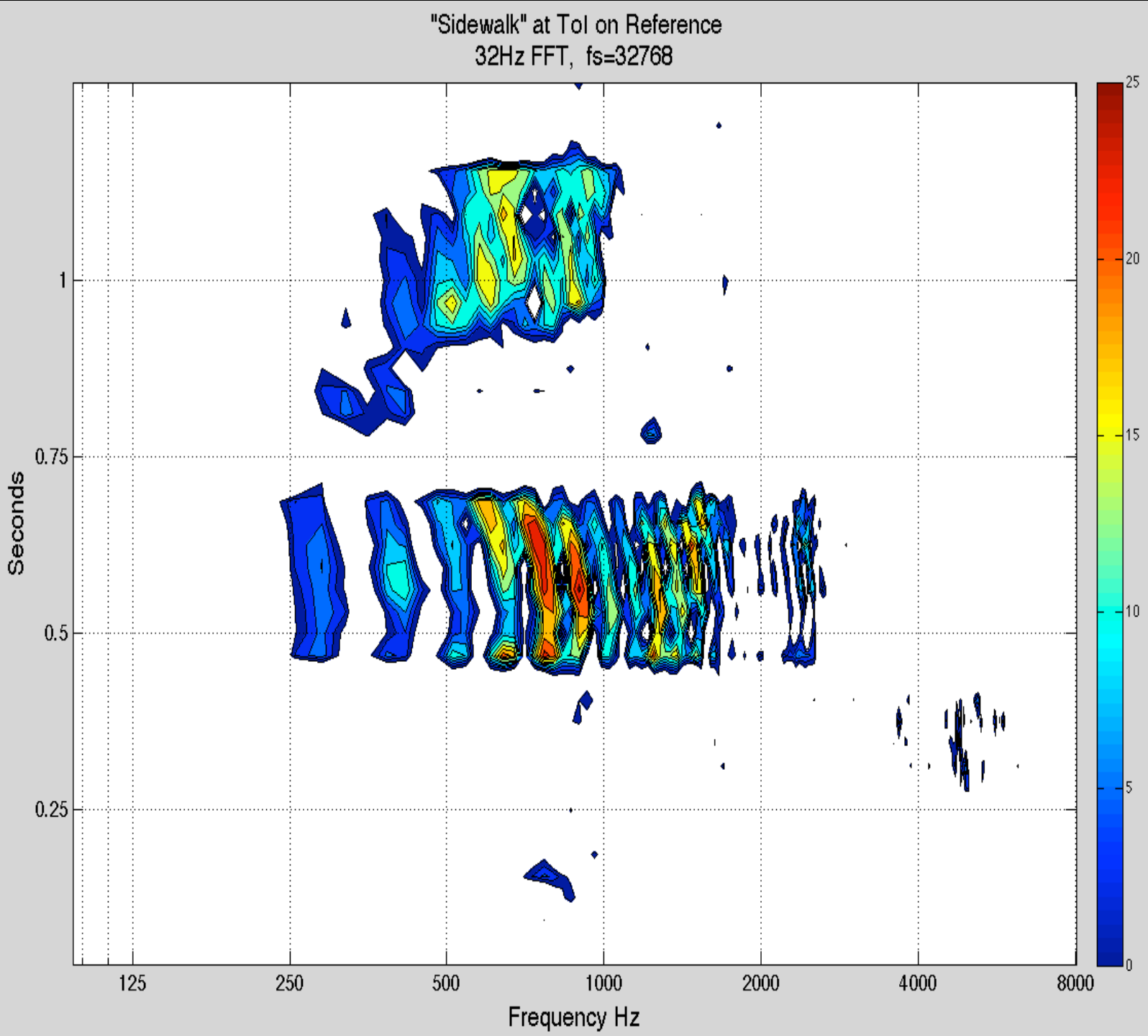
Max dB=42.4

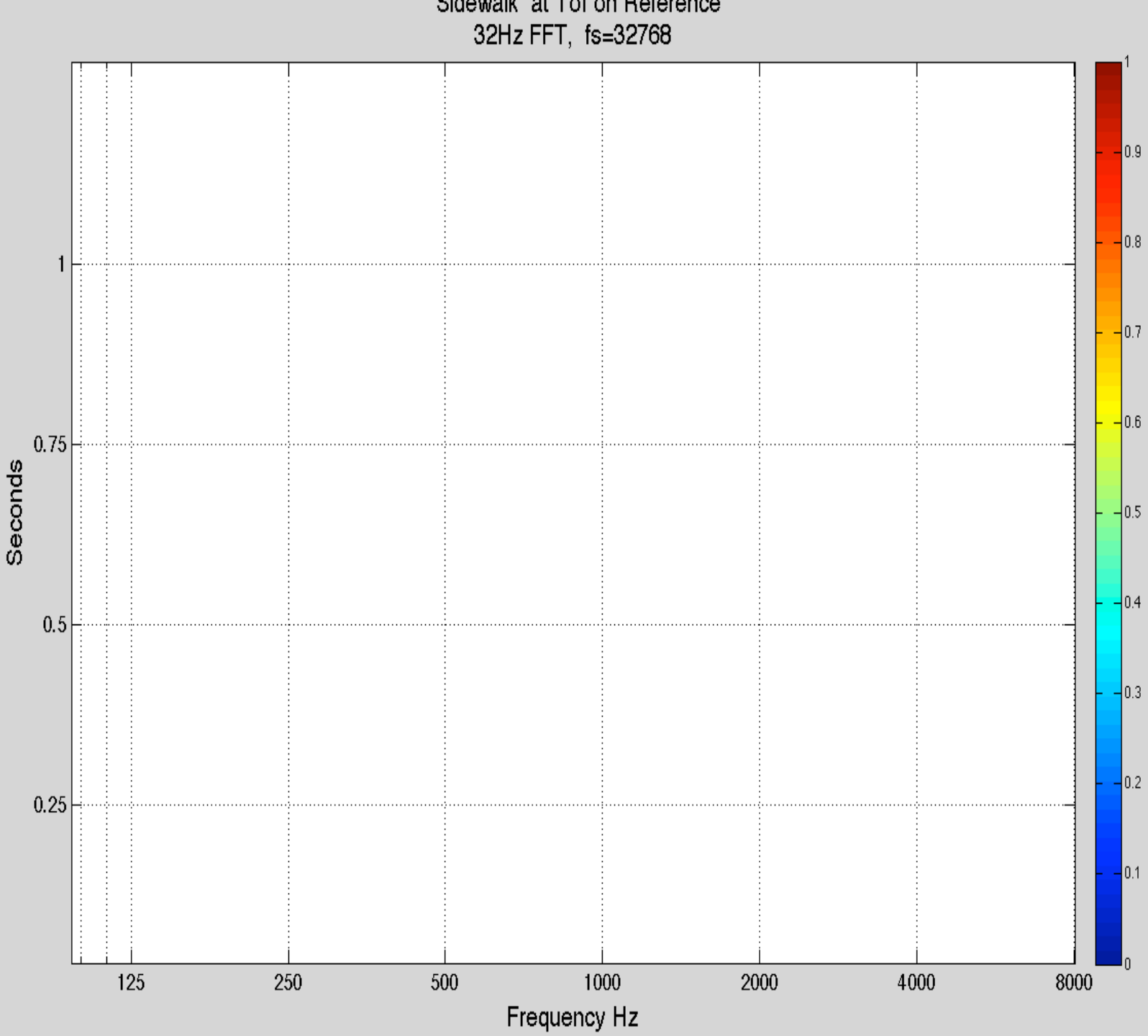
28/JAN/2009


"Horseshoe" at TOI on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
25
20
15
10
5
0

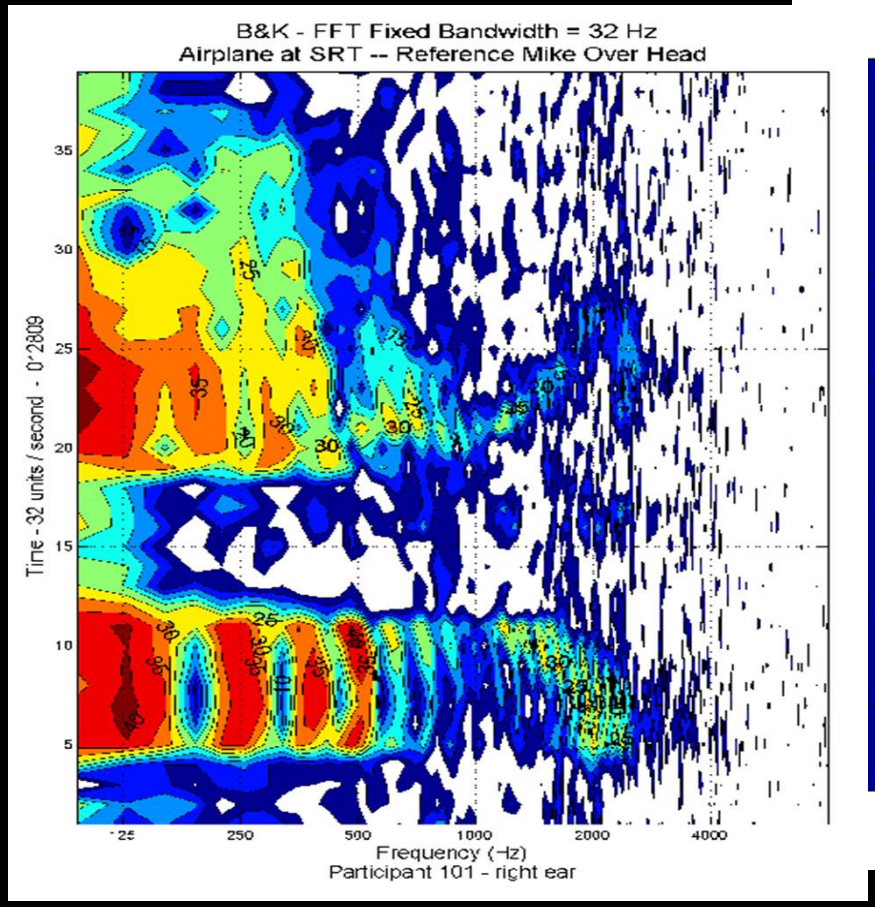

Horseshoe at Tor on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
Frequency Hz
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

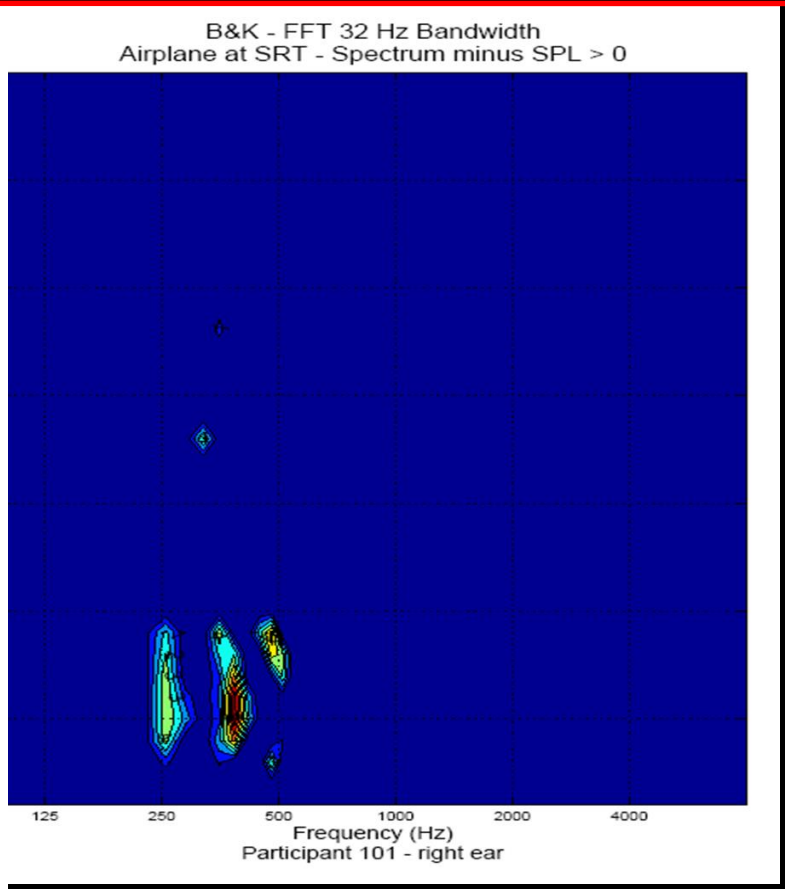

"Sidewalk" at Tol on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
Frequency Hz
35
30
25
20
15
10
5
0

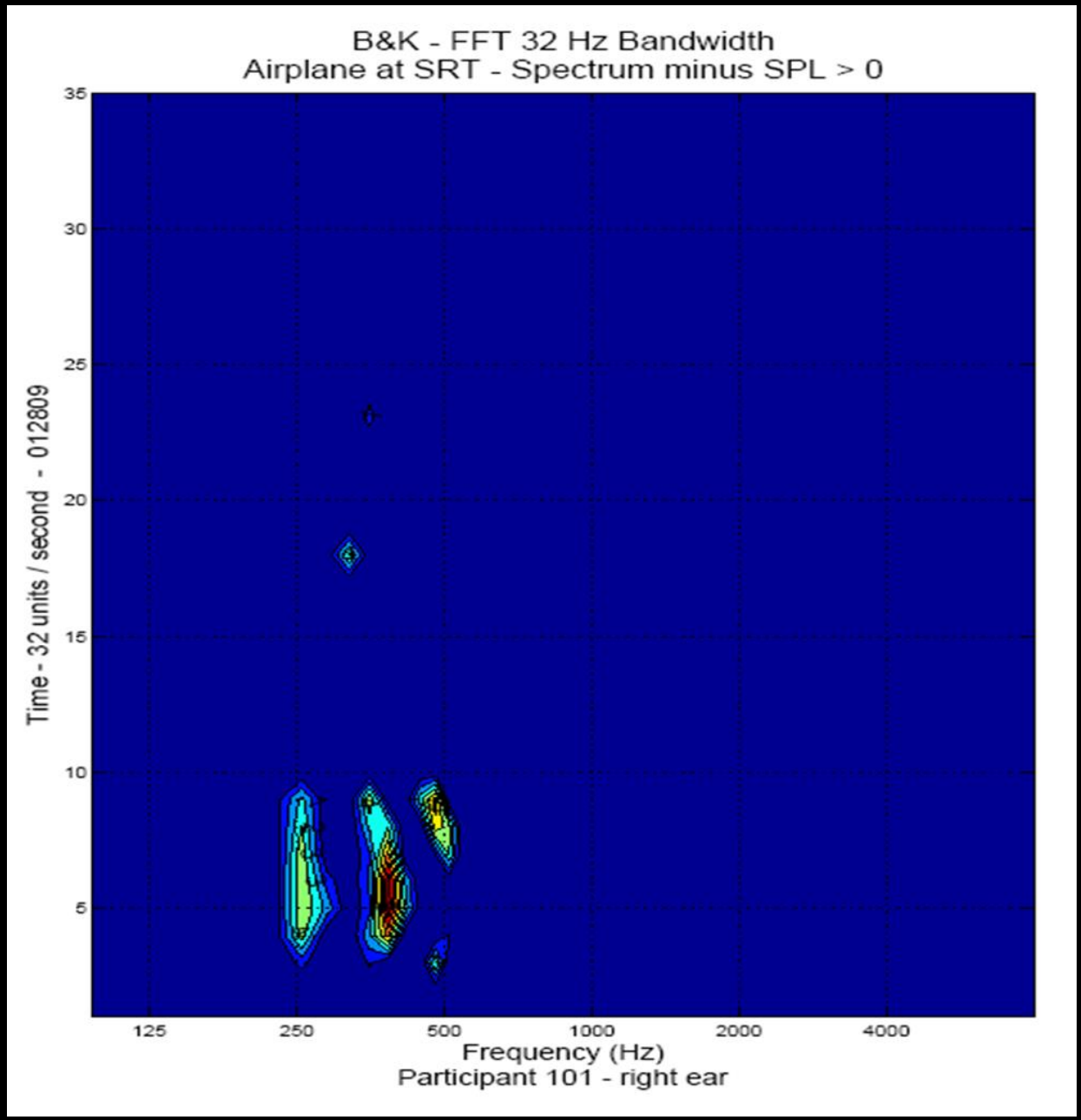

"Sidewalk" at ToI on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
Frequency Hz
25
20
15
10
5
0

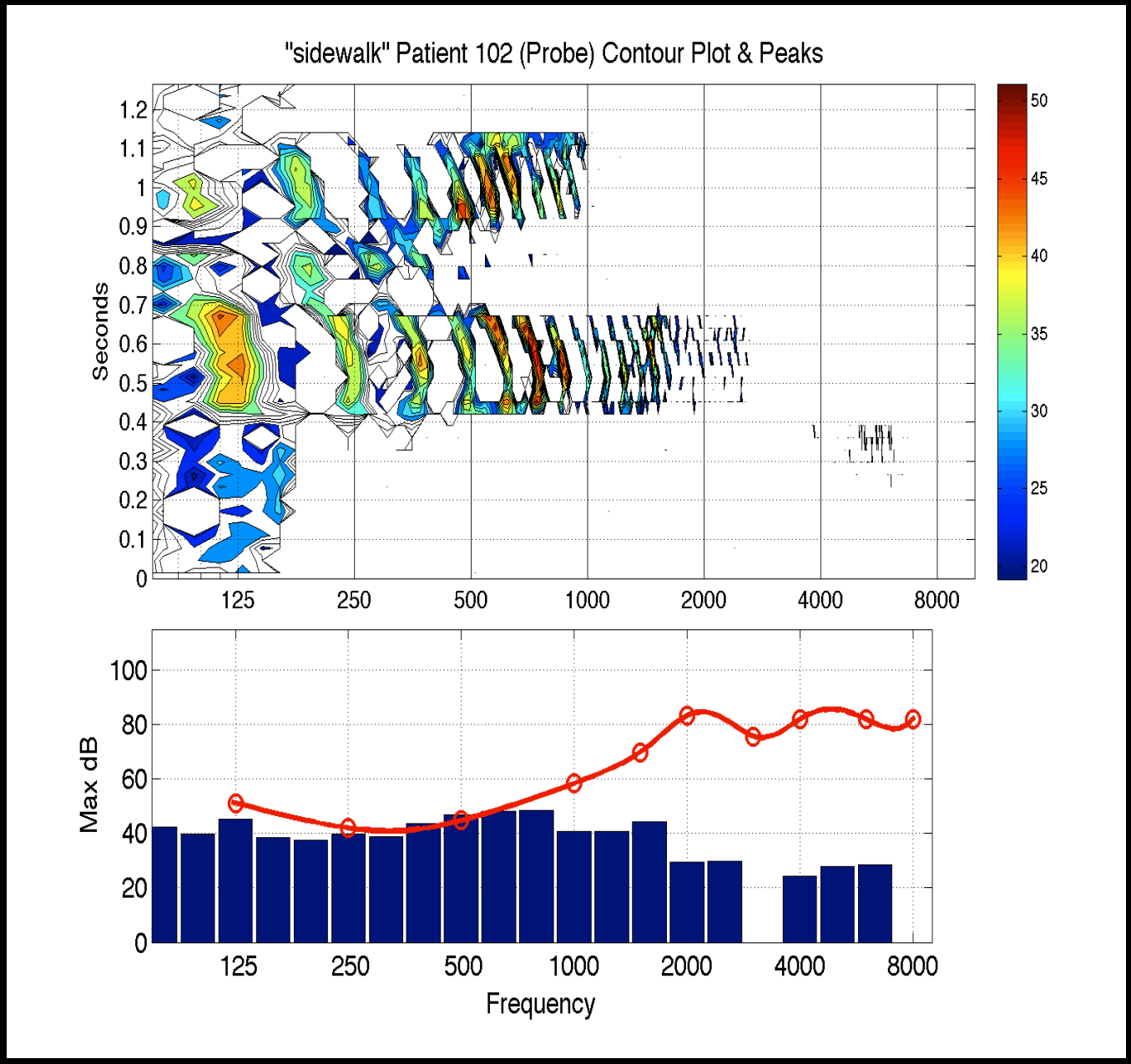

Sidewalk at Tol on Reference
32Hz FFT, fs=32768
Seconds
1
0.75
0.5
0.25
125
250
500
1000
2000
4000
8000
Frequency Hz
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

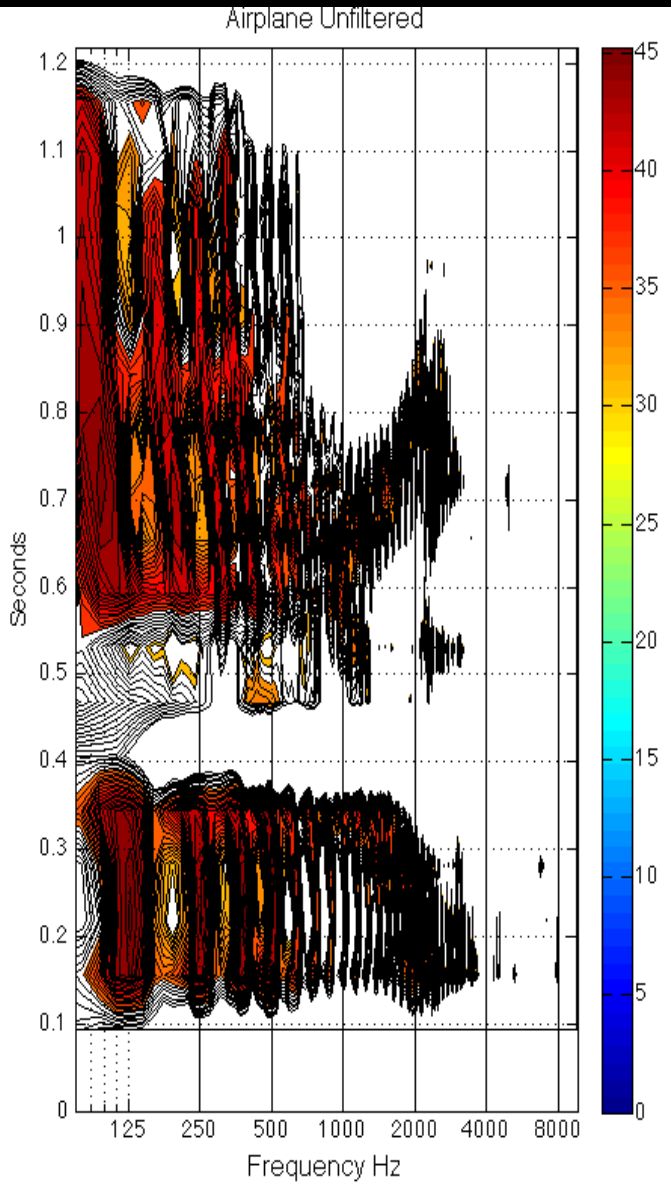
Airplane at SRT compared to SPL

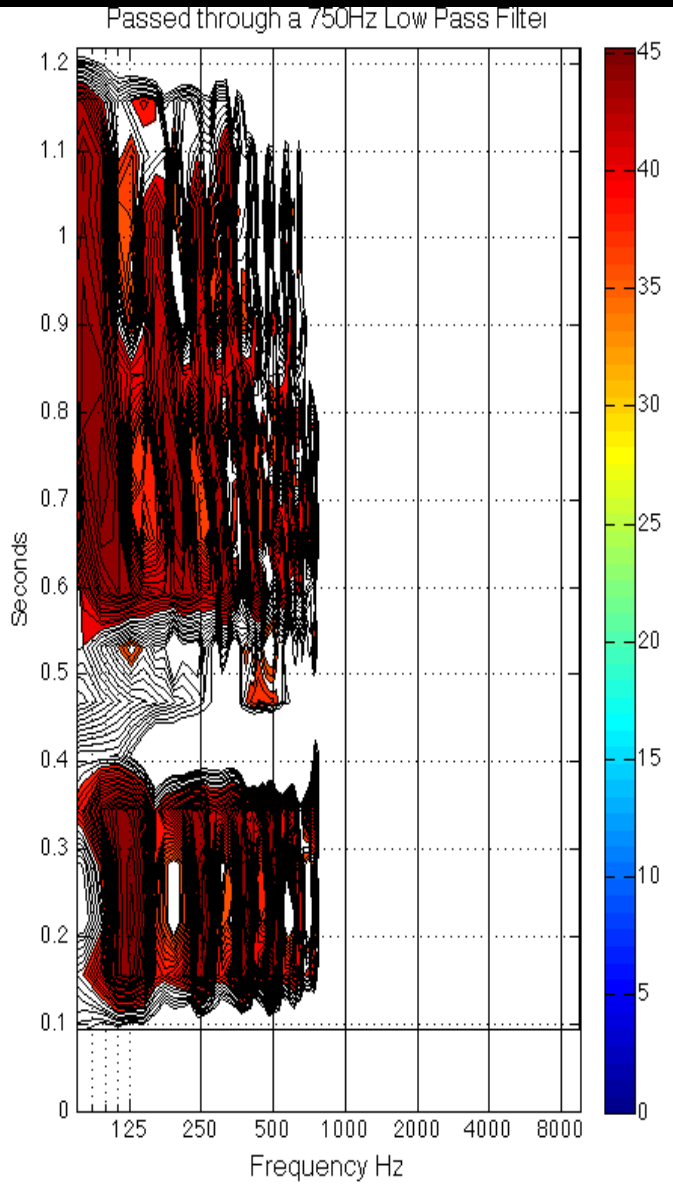


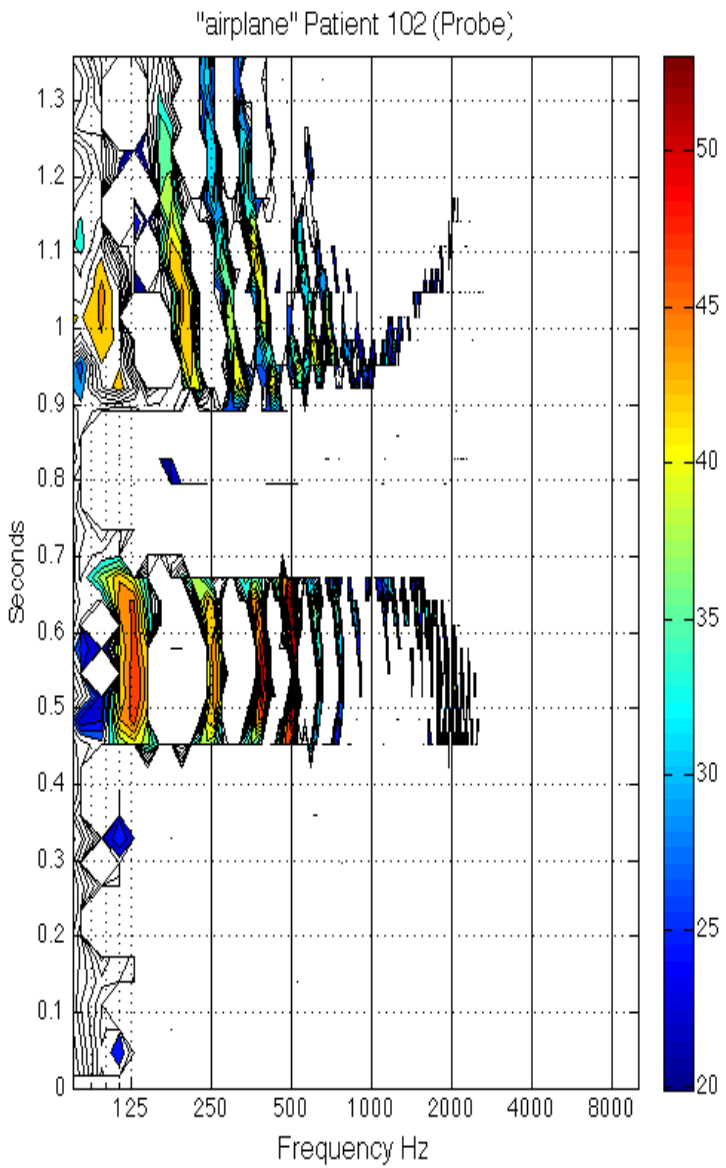


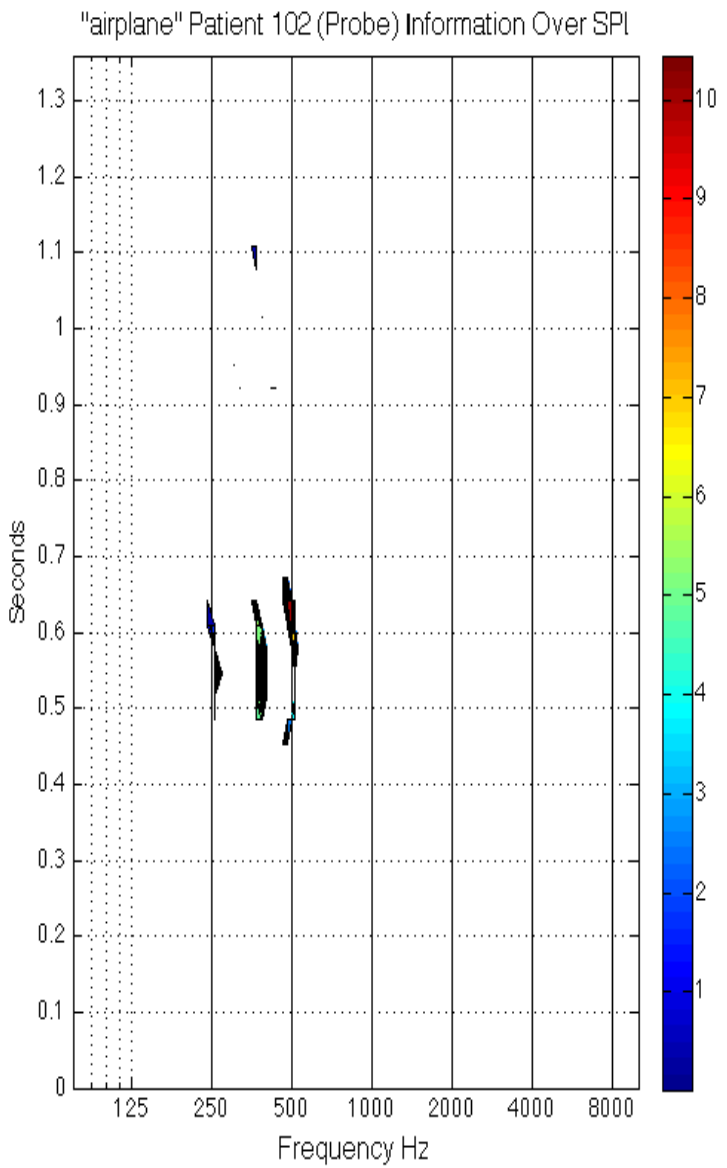

B&K - FFT 32 Hz Bandwidth
Airplane at SRT - Spectrum minus SPL > 0
Time - 32 units / second - 012809
35
30
25
20
15
10
5
125
250
500
1000
2000
4000
Frequency (Hz)
Participant 101 - right ear

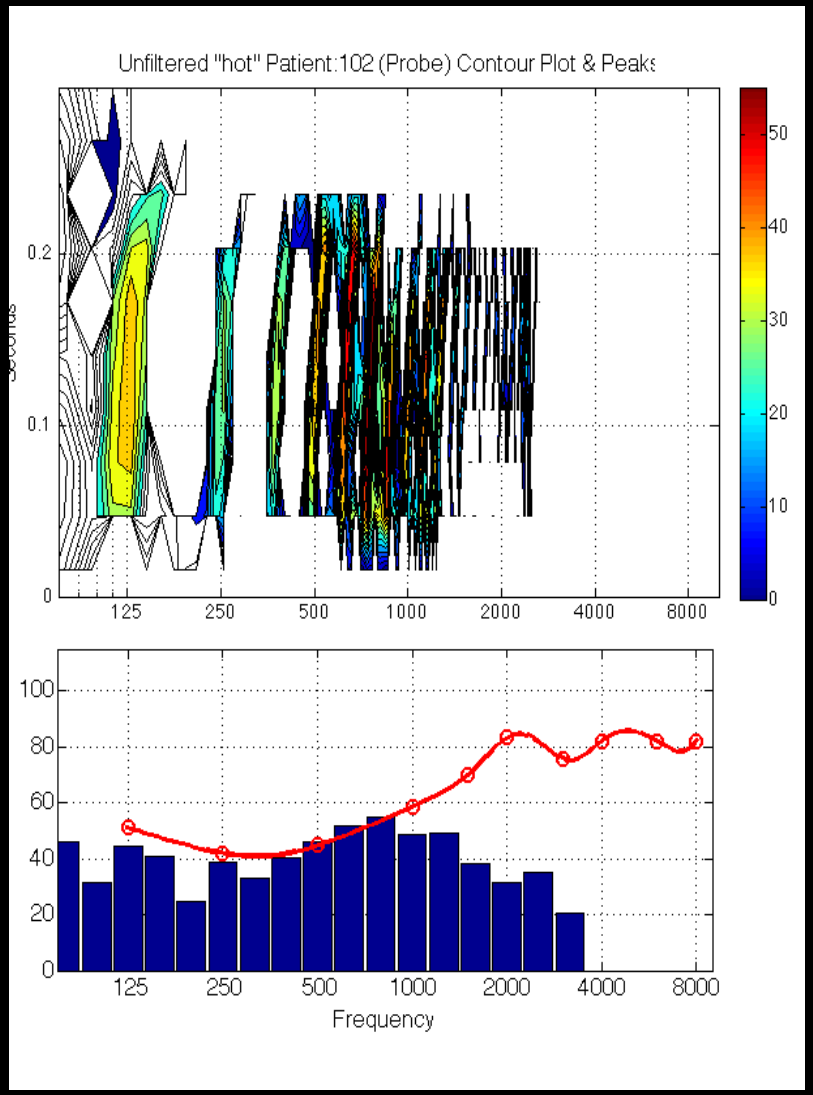

"sidewalk" Patient 102 (Probe) Contour Plot & Peaks
Seconds
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
125
250
500
1000
2000
4000
8000
50
45
40
35
30
25
20
Max dB
100
80
60
40
20
0
125
250
500
1000
2000
4000
8000
Frequency

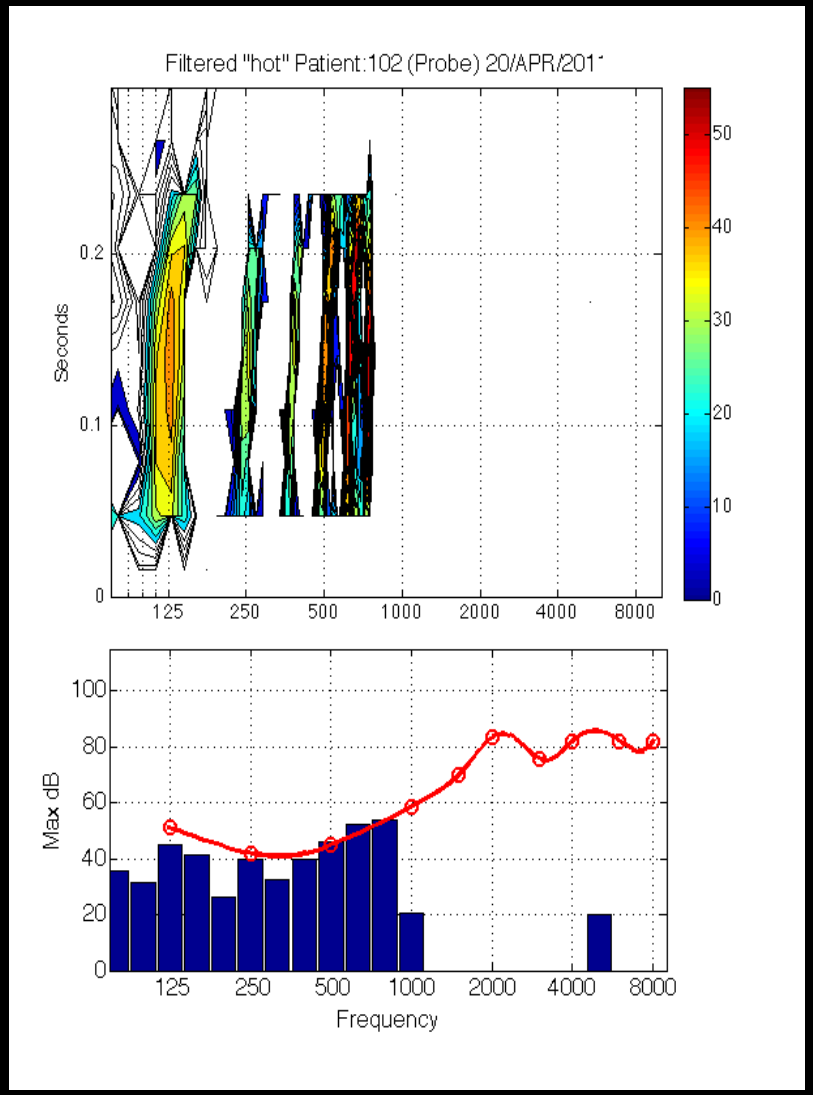

Airplane Unfiltered
Seconds
Frequency Hz
125
250
500
1000
2000
4000
8000


Passed through a 750Hz Low Pass Filter
Seconds
Frequency Hz
125
250
500
1000
2000
4000
8000

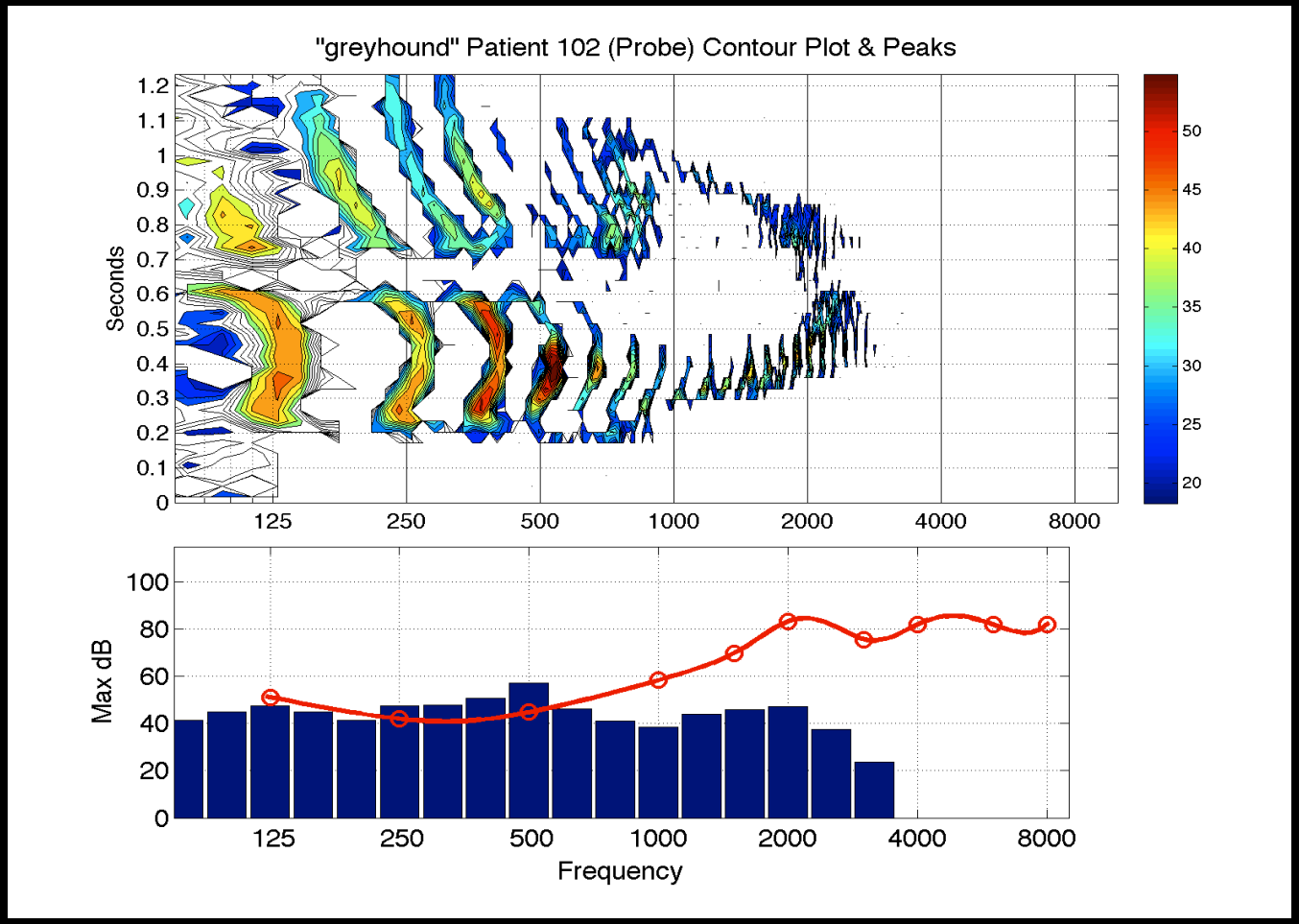

"airplane" Patient 102 (Probe)
Seconds
Frequency Hz
125
250
500
1000
2000
4000
8000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
20
25
30
35
40
45
50


"airplane" Patient 102 (Probe) Information Over SPI
Seconds
Frequency Hz
125
250
500
1000
2000
4000
8000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1
2
3
4
5
6
7
8
9
10


Unfiltered "hot" Patient:102 (Probe) Contour Plot & Peaks
Seconds
0
0.1
0.2
125
250
500
1000
2000
4000
8000
0
10
20
30
40
50
Max dB
0
20
40
60
80
100
Frequency


Filtered "hot" Patient:102 (Probe) 20/APR/201
Seconds
0
0.1
0.2
125
250
500
1000
2000
4000
8000
0
10
20
30
40
50
Max dB
0
20
40
60
80
100
Frequency

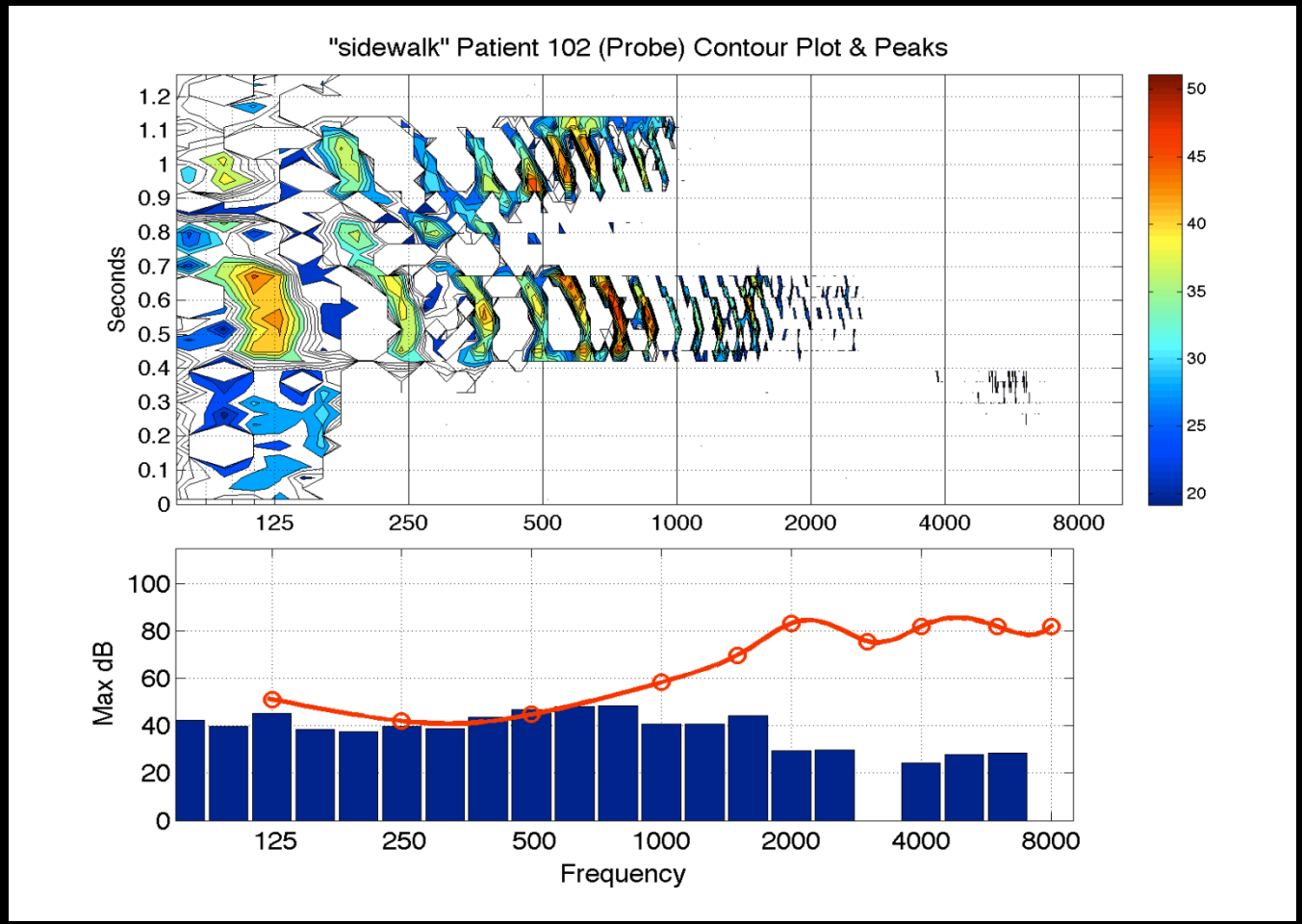
Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at
"Soft Speech"

✓ Word Perceived
(greyhound)

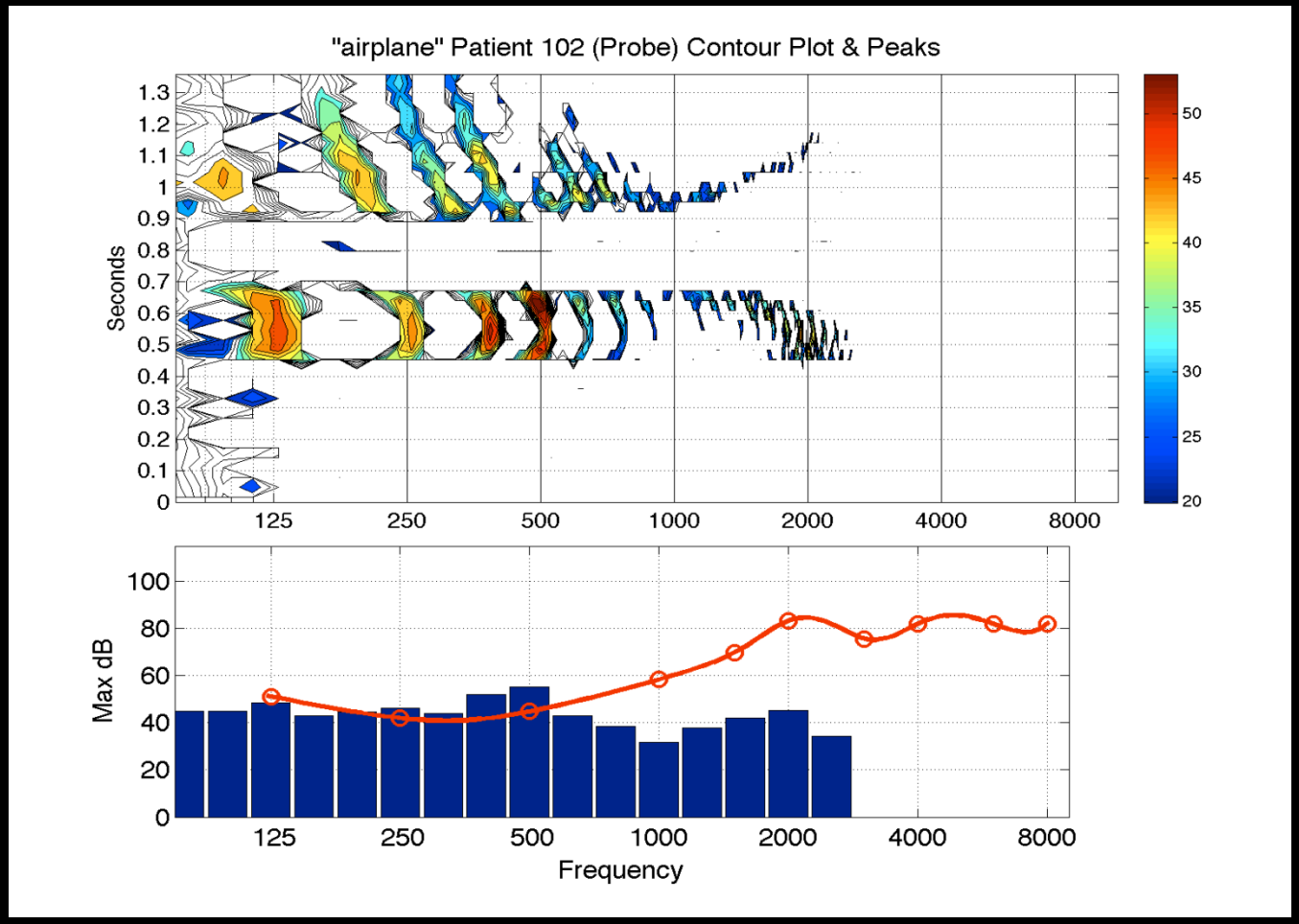
Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at "Soft Speech"

✓ Word Perceived (sidewalk)

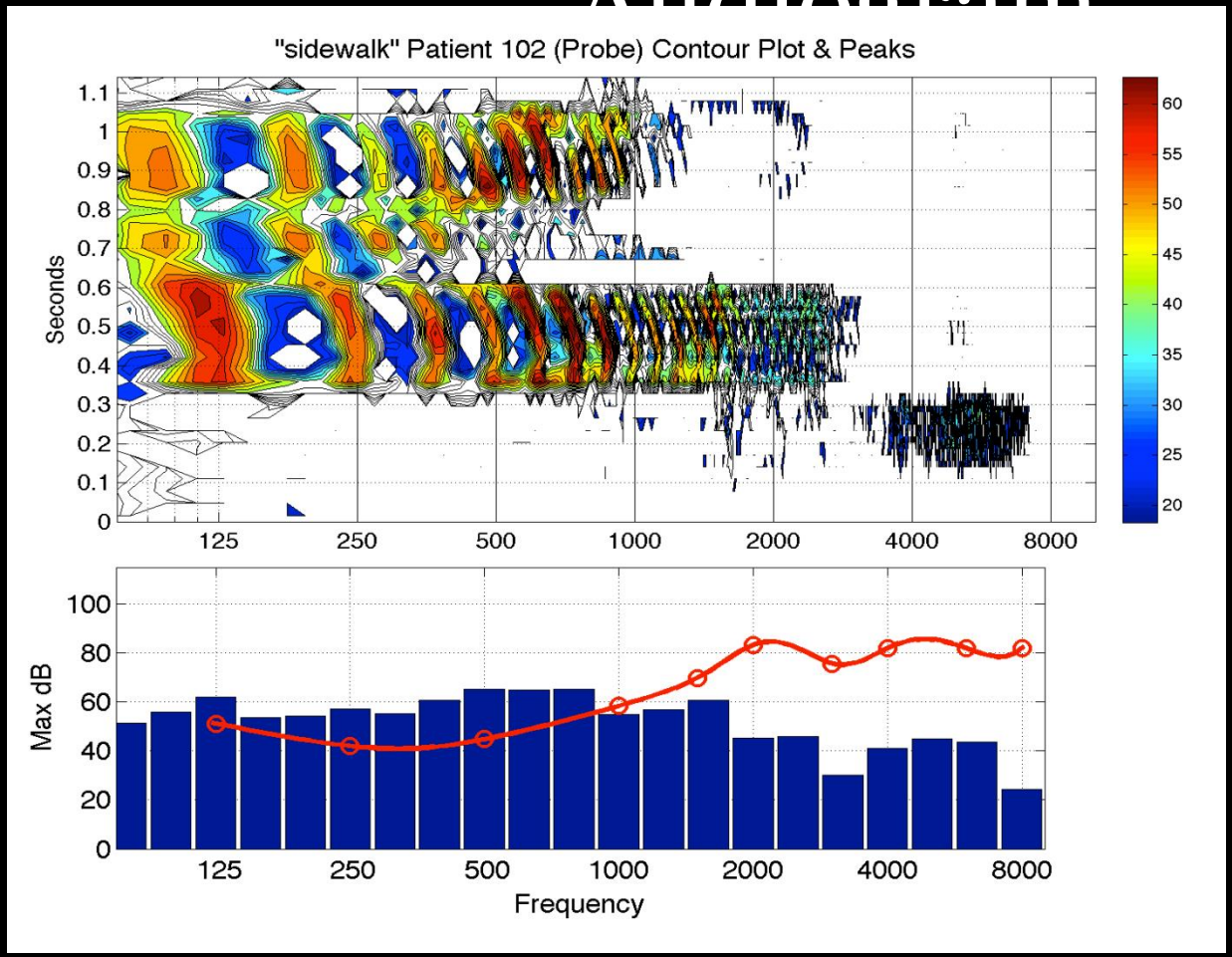
Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at "Soft Speech"

✓ Word Perceived (airplane)

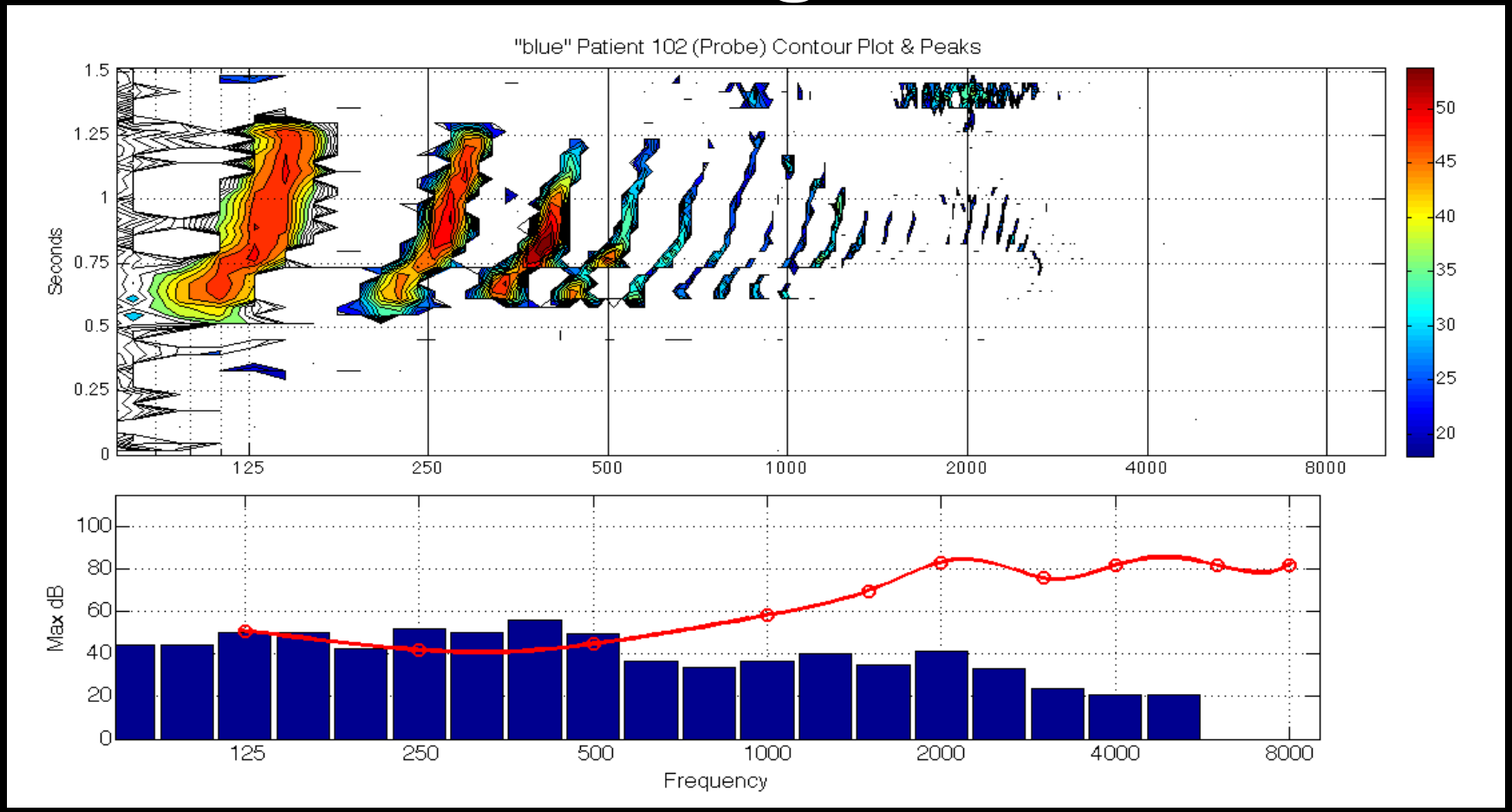
Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at "Normal Intensity"

✓ Word Perceived (sidewalk)

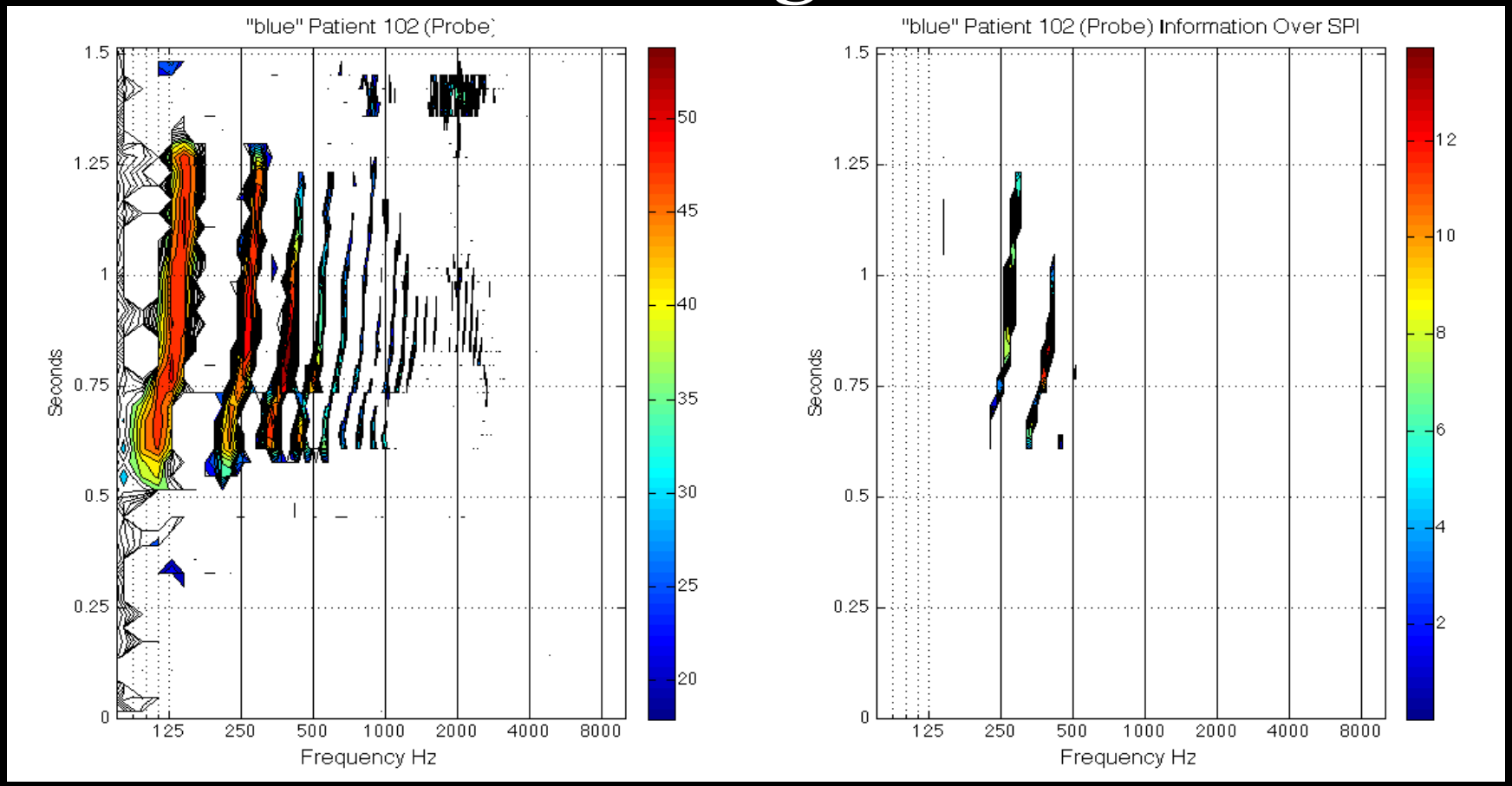
Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at “Soft Speech”

✓ Word Perceived (blue)

Comparing SPL Energy Measured by the Probe Microphone to SPL Audiogram



Presented at “Soft Speech” ✓ Word Perceived (blue)

Section VI

Case Studies

B H S S

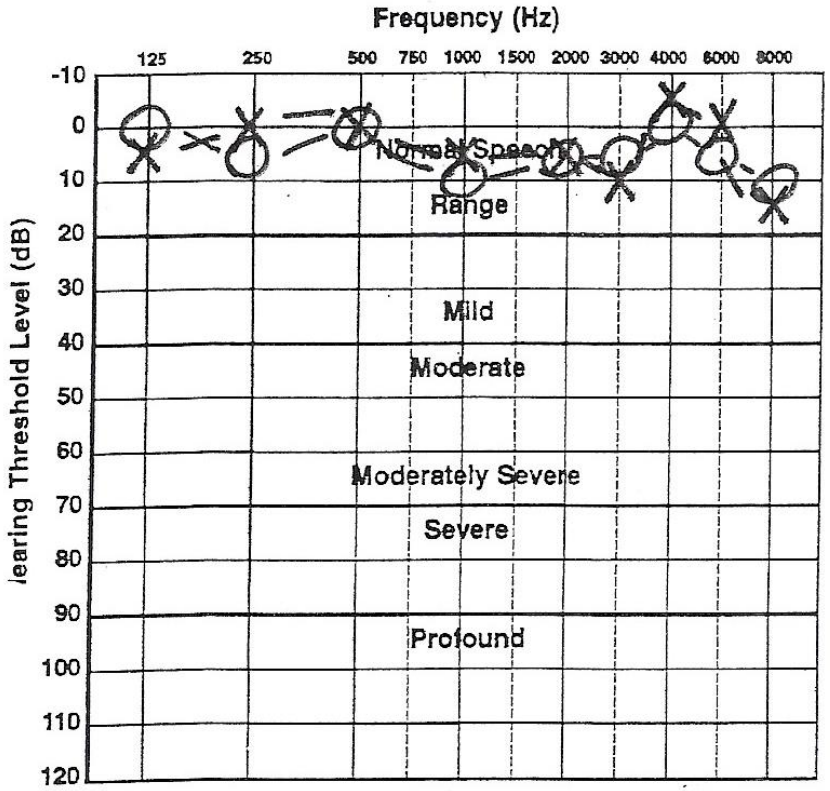
BLOUNT HEARING & SPEECH SERVICES, INC.

1617 East Broadway • Maryville, Tennessee 37804 • Phone (865) 982-8557 • FAX (865) 982-8599

Name [redacted] Age 30 Date 10/24/08

Audiometer GSI 61 (inserts) Examiner N. McAmis, MA, CCC-A

Initial ✓ Re-evaluation _____ Test Reliability Good ✓ Fair _____ Poor _____



Most Comfortable Level	LE _____	RE _____
Threshold of Discomfort	LE _____	RE _____
Pure Tone Average	LE _____	RE _____
Speech Reception Thr.	LE 5dB	RE 10dB

Speech Discrimination Score Stimuli _____

Right Ear	_____ %	_____ %	_____ %
	____/____ dB masking	____/____ dB masking	____/____ dB masking
Left Ear	_____ %	_____ %	_____ %
	____/____ dB masking	____/____ dB masking	____/____ dB masking

Tonality Test Results

	L	LM	M	MH	H
Right	_____ %	_____ %	_____ %	_____ %	_____ %
Left	_____ %	_____ %	_____ %	_____ %	_____ %

BHSS

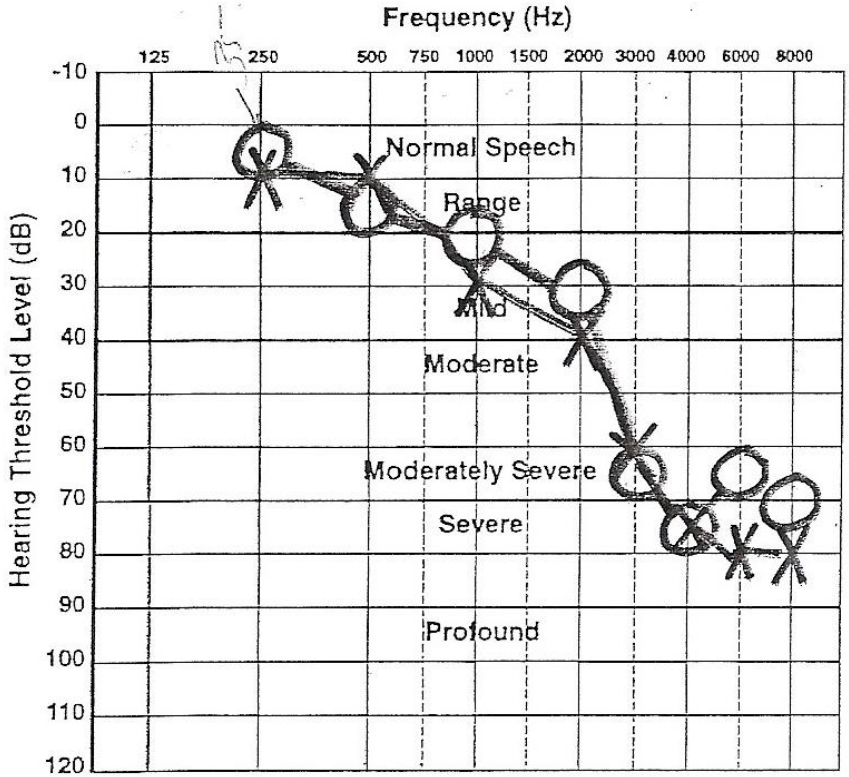
BLOUNT HEARING & SPEECH SERVICES, INC.

1617 East Broadway • Maryville, Tennessee 37804 • Phone (865) 982-8557 • FAX (865) 982-8599

Name [redacted] Age _____ Date 3-26-2010

Audiometer GSI 61 123 Examiner Rook

Initial _____ Re-evaluation _____ Test Reliability Good ✓ Fair _____ Poor _____



Most Comfortable Level	LE 55	RE 55
Threshold of Discomfort	LE _____	RE _____
Pure Tone Average	LE _____	RE _____
Speech Reception Thr.	LE 15	RE 20

Speech Discrimination Score Stimuli W22 CD

Right Ear	96 %	_____ %	_____ %
	55 / _____ dB masking	_____ / _____ dB masking	_____ / _____ dB masking
Left Ear	100 %	_____ %	_____ %
	55 / _____ dB masking	_____ / _____ dB masking	_____ / _____ dB masking

Tonality Test Results

	L	LM	M	MH	H
Right	_____ %	_____ %	_____ %	_____ %	_____ %
Left	_____ %	_____ %	_____ %	_____ %	_____ %

Patient: **Spectrally Distinct Word Test Score Sheet** **Date:**

Ear L/R (R) **Conditions:** 19ft Unaided opposite ear plugged

Low			Low Medium			Middle			Middle High			High		
Word	Score	Error	Word	Score	Error	Word	Score	Error	Word	Score	Error	Word	Score	Error
Blue	+		Know	+		Have	+		Lot	+		See	+	
new	+		Bone	-+		add	+		rock	+		she	+	
Room	+		now	+		cat	+		Tack	-+	patch	cheap	+	
Move	-+	new	row	+		hat	-+	pat	Fat	-+	pat	sheet	-+	sleep
Wood	+		bow	-+	so	hot	+		ice	+		seek	-+	se

%80 %60 %80 %60 %60

1st Presentation 68 2nd Presentation 24 Comments:

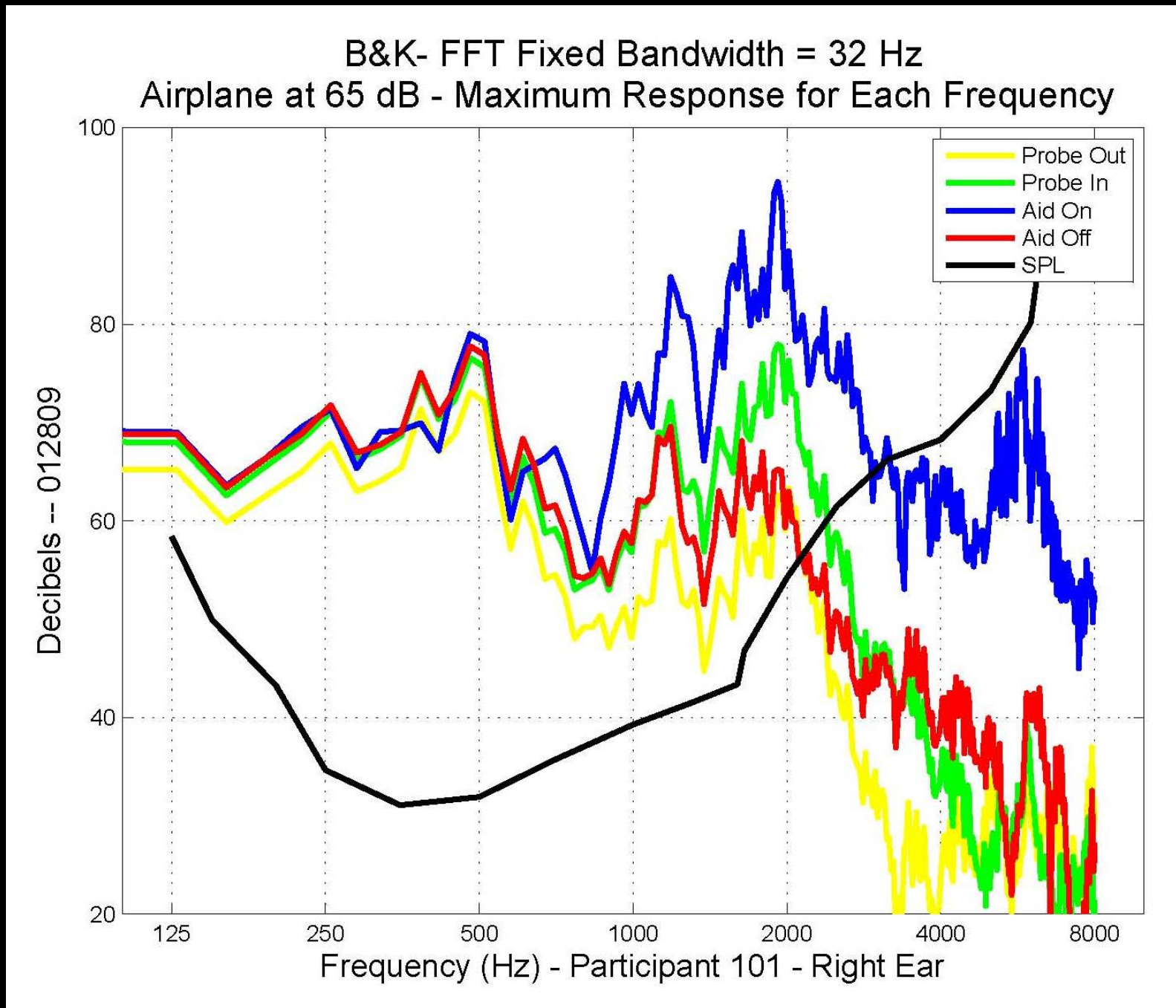
Patient: **Spectrally Distinct Word Test Score Sheet** **Date:**

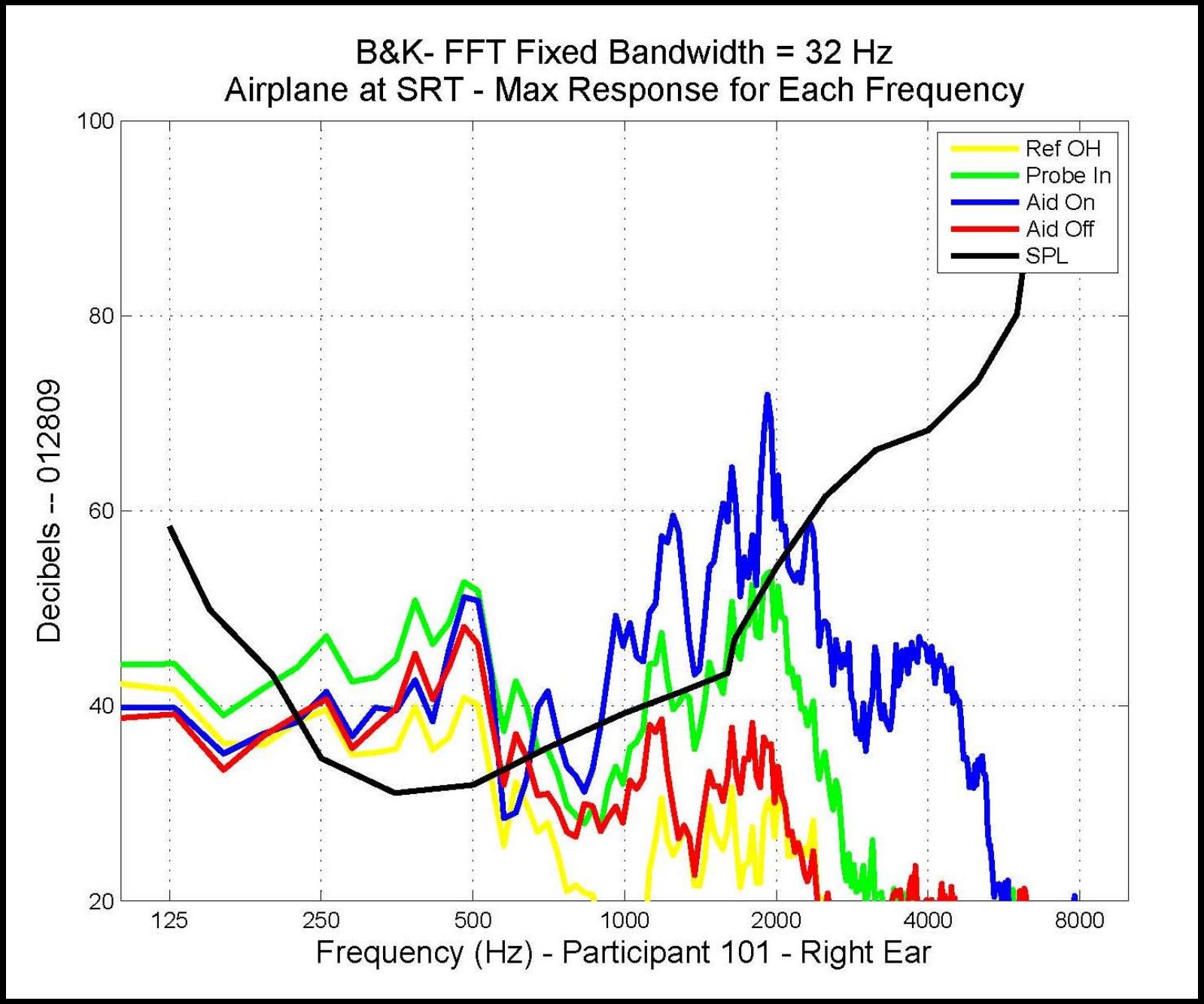
Ear (L)/R **Conditions:** 19ft. UNAided opposite ear Plugged.

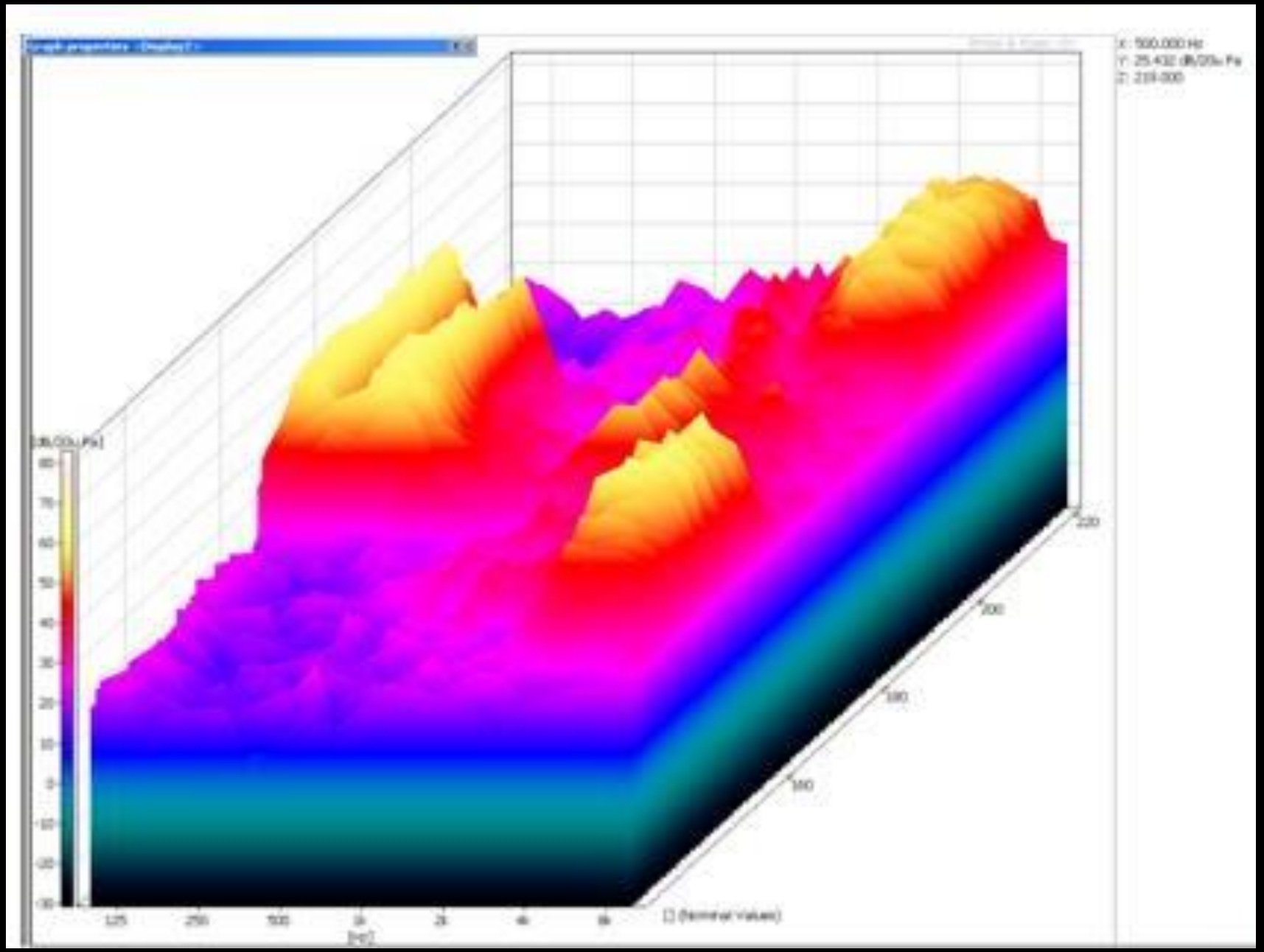
Low			Low Medium			Middle			Middle High			High		
Word	Score	Error	Word	Score	Error	Word	Score	Error	Word	Score	Error	Word	Score	Error
blue	+		know	+		Have	-+	cat	six	+		see	---	u
new	+		Bone	+		add	+		Rock	+		She	---	chee
Room	+		now	+		Cat	+		Tack	---	mack	Cheap	---	Teach
Move	-+	news	row	+		hat	+		Tap	---	pap	Sheet	---	eat
Wood	+		bow	+		hot	+		Fat	---	Tap	seat	---	eat

%80 %100 %80 %40 %0

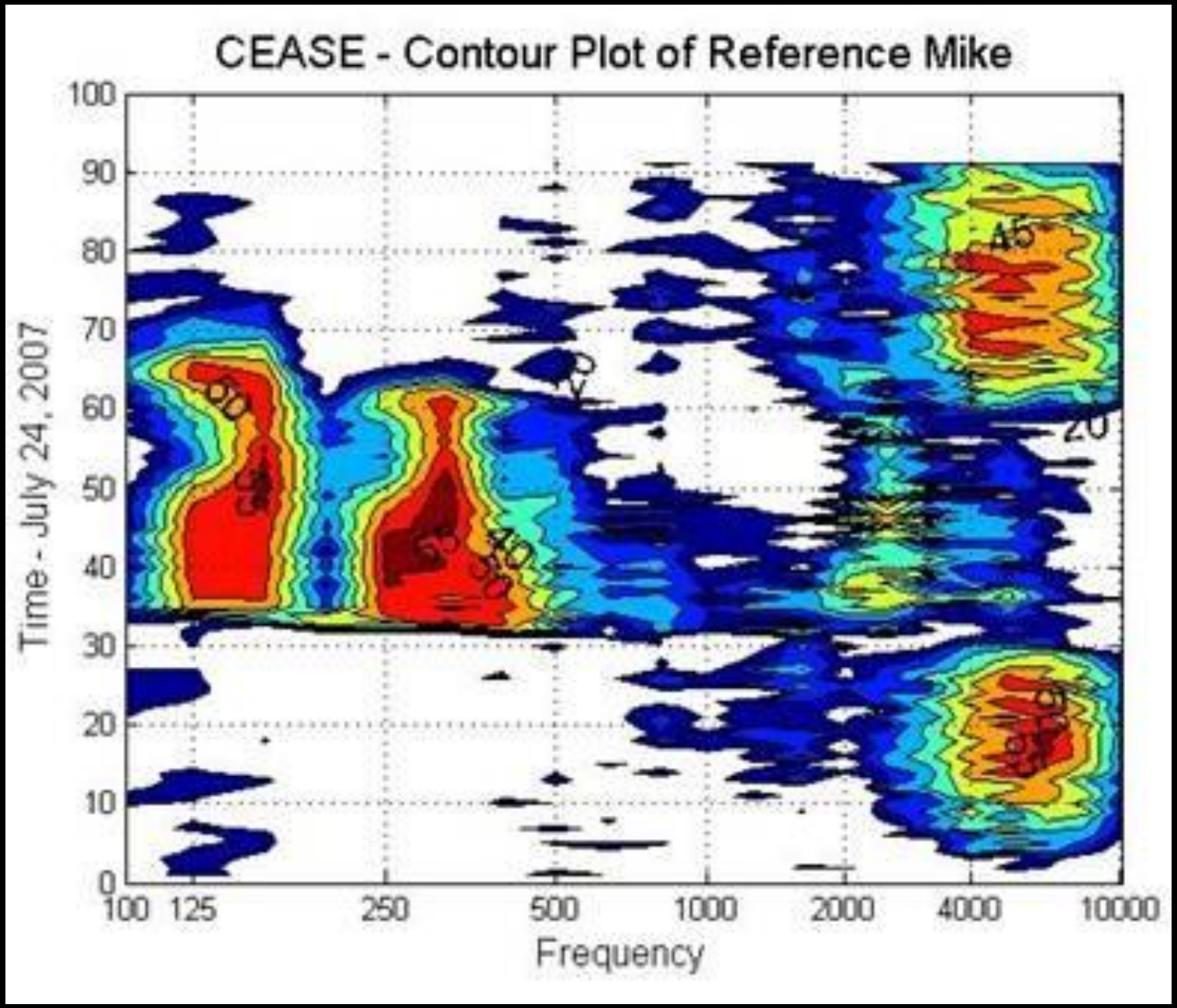
1st Presentation 60 2nd Presentation 8 Comments:

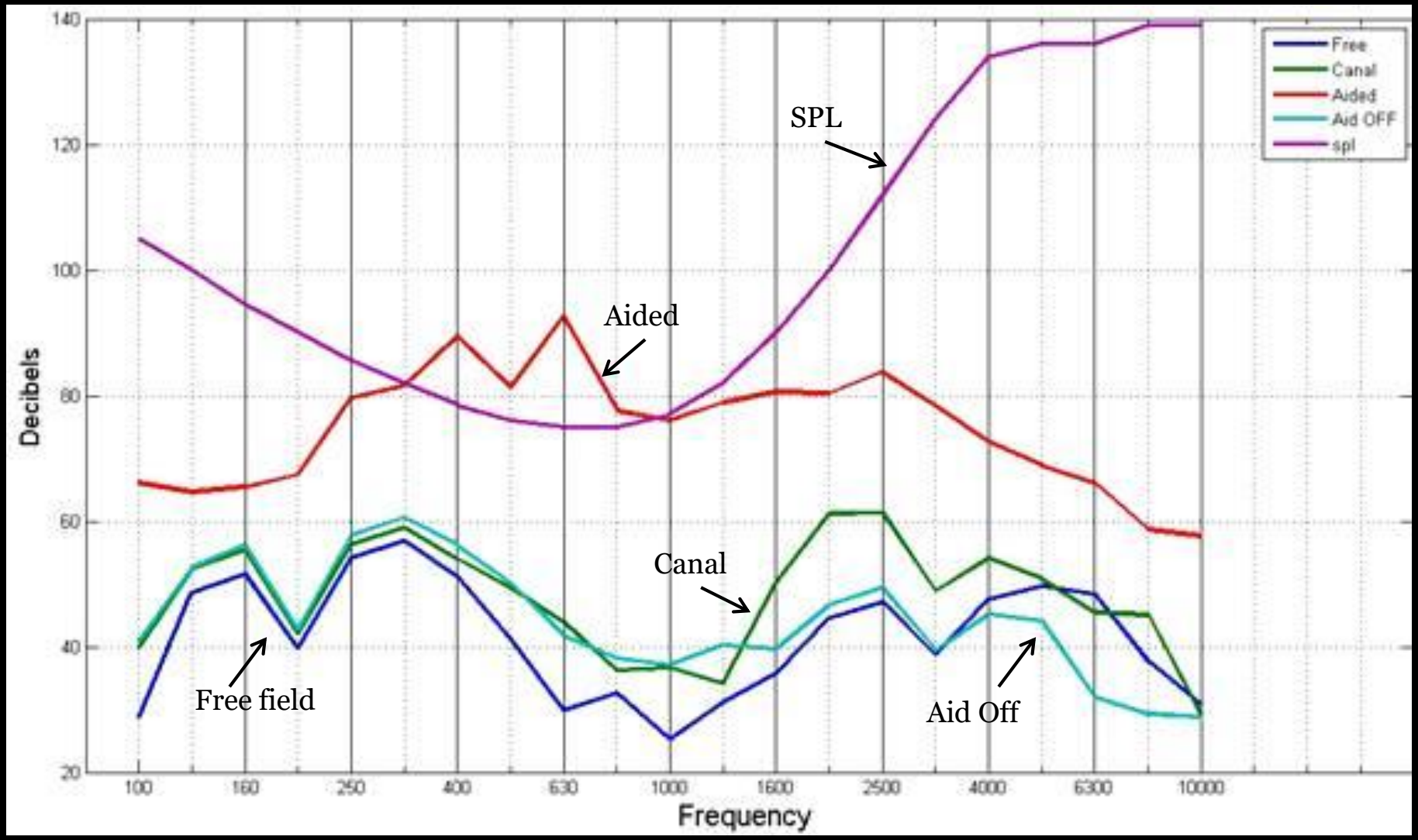

B&K- FFT Fixed Bandwidth = 32 Hz
Airplane at 65 dB - Maximum Response for Each Frequency
Probe Out
Probe In
Aid On
Aid Off
SPL
100
80
60
40
20
Decibels -- 012809
125
250
500
1000
2000
4000
8000
Frequency (Hz) - Participant 101 - Right Ear


B&K- FFT Fixed Bandwidth = 32 Hz
Airplane at SRT - Max Response for Each Frequency
Ref OH
Probe In
Aid On
Aid Off
SPL
100
80
60
40
20
Decibels -- 012809
125
250
500
1000
2000
4000
8000
Frequency (Hz) - Participant 101 - Right Ear



Modern waterfall of “cease” through reference microphone


CEASE - Contour Plot of Reference Mike
Time - July 24, 2007
Frequency
100
90
80
70
60
50
40
30
20
10
0
100
125
250
500
1000
2000
4000
10000
45
50
40
30
20


Free
Canal
Aided
Aid OFF
spl
SPL
Aided
Canal
Free field
Aid Off
Decibels
Frequency
140
120
100
80
60
40
20
100
160
250
400
630
1000
1600
2500
4000
6300
10000

Conclusion

- The perceptual pitch ranking of the tonality words is predicted by the energy in specific octave frequency bands.
- The resonance of the ear canal improves the detection of information in speech .
- Ranking the tonality words can be achieved using the extreme octave bands.
  - These discontinuous extremes provide more information than the words passed by the telephone.
  - Note: Most people do perceive the words via the middle frequency bands.

Directions to the Patient

"Do not guess at the words.

Just try to imitate what you hear.

Even if it doesn't sound like a word repeat what sounds you hear.

Tell me if you are straining to hear the words.

Please look down to avoid visual cues."

Directions to the Patient

"Do not guess at the words.

Just try to imitate what you hear.

Even if it doesn't sound like a word repeat what sounds you hear.

Tell me if you are straining to hear the words.

Please look down to avoid visual cues."

Using the Tonality Words - Test Score Sheet

This test uses frequency balanced word at a most comfortable distance to see what effect the damaged ear has on the perception of different frequencies in speech.

Ear **Right** Conditions:

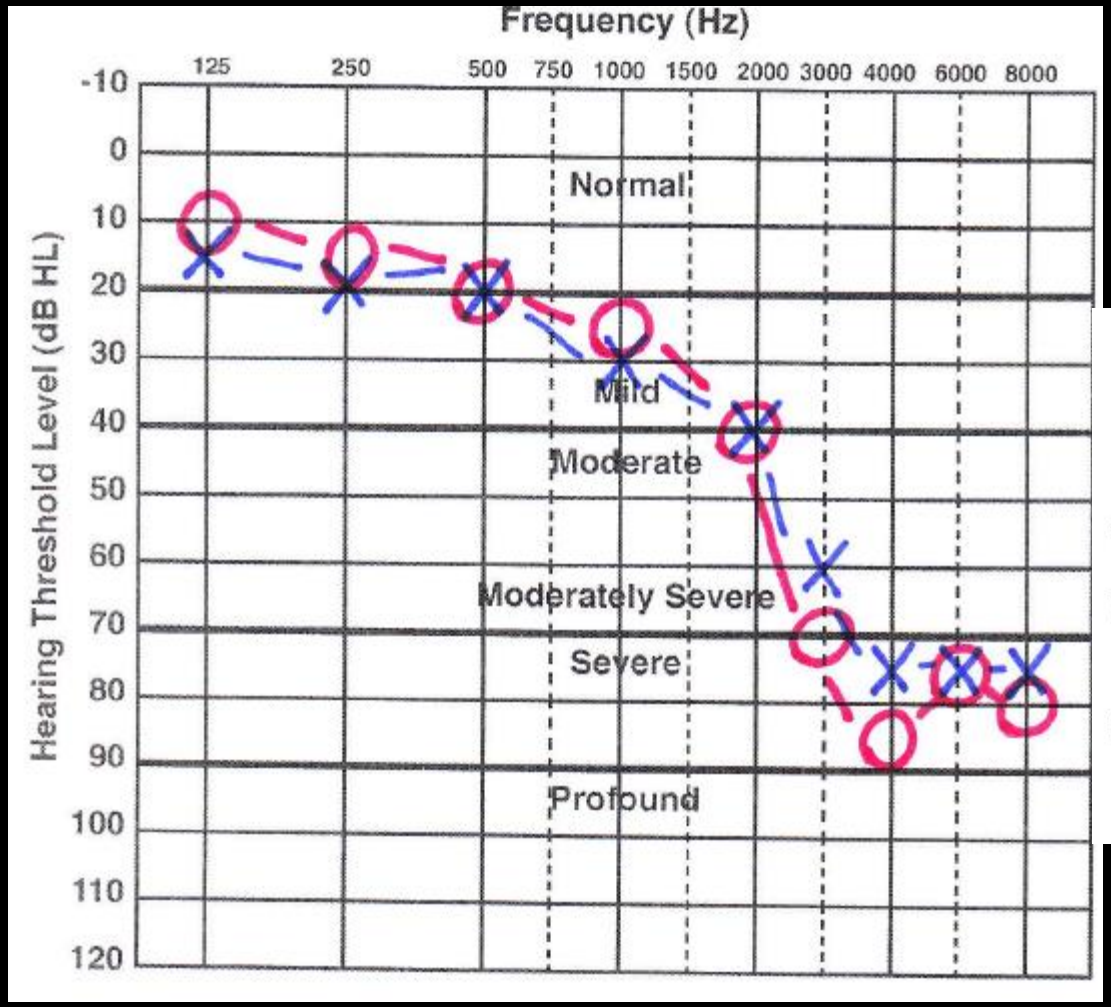
Low			Low-Middle			Middle			Middle-High			High		
	Score	Error		*Score*	Error		*Score*	Error		*Score*	Error		*Score*	Error
bow (bō)			gum			void			hire			is		
prune			wall			talk			it			sake		
noun			boat			hall			kit			sheet		
warm			one			drum			ill			thigh		
wool			bump			hair			lie			sit		
	____%			____%			____%			____%			____%	

1st Presentation _____ 2nd Presentation _____ Comments: _____

Performing and Scoring the Tonality Word Test

- Each ear is tested separately (with opposite ear plugged).
- Distance from patient is determined by finding a conversational comfortable distance.
- Words are presented one at a time. If the patient misses the word it can be repeated .
- Responses are recorded on the score sheet with a “+” indicating correct, “-” indicated incorrect.
- On incorrect responses if the patient indicated a higher frequency category word an “ ↑ " is recorded, if a missed word is from a lower category, an " ↓ ” is indicated on the score sheet.
- **When the person repeats the words 50% or more on the second presentation it is an indication that the intensity level was not loud enough (i.e. the distance chosen was incorrect).

Patient's audiogram



	MCL	LE 60 dB	RE 60 dB
	UCL	LE 100 dB	RE 95 dB
	PTA	LE ____ dB	RE ____ dB
(SRT)	SAT	LE 20 dB	RE 20 dB

Word Recognition Score: MLV ∞ Recorded ____ **Stimuli:** Nu-6 ∞ CID W-22 ____

Right Ear	84 %	____ %	____ %
	60 / — dB HL/masking	____ / ____ dB HL/masking	____ / ____ dB HL/masking
Left Ear	96 %	____ %	____ %
	60 / — dB HL/masking	____ / ____ dB HL/masking	____ / ____ dB HL/masking

Unaided Tonality Word Test

Patient: 104

Ear **Right** Conditions: UNAIDED at 6 feet

Low			Low-Middle			Middle			Middle-High			High		
	Score	Error		*Score*	Error		*Score*	Error		*Score*	Error		*Score*	Error
blue	+		**boat**	+		**hot**	+		**tie**	- - -	–	**itch**	- - -	–
no	+		**good**	- - -	–	**cat**	- - -	–	**kit**	- - -	–	**see**	- - -	–
row	- - -	–	**comb**	- - -	–	**knock**	- - -	–	**kite**	- - -	–	**she**	- - -	–
prune	- - -	–	**top**	- - -	–	**top**	- +		**jet**	- - -	–	**cease**	- - -	–
pull	- - -	–	**up**	- - -	–	**tack**	- - -	–	**ice**	- - -	–	**teach**	- - -	–
40% %			20% %			20% %			0 %			0 %		

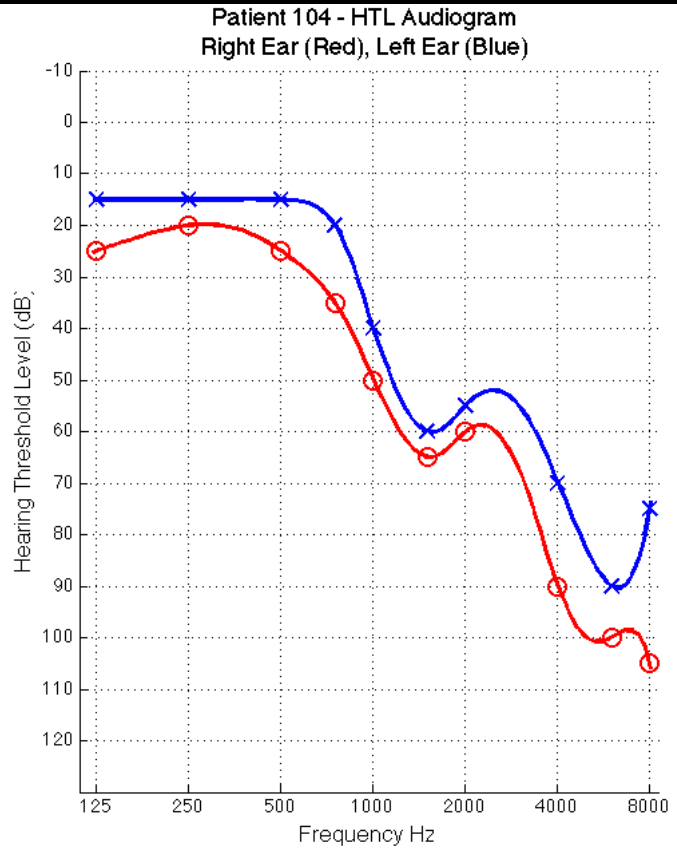
t Presentation 16% 2nd Presentation 4% Total 20% Comments:

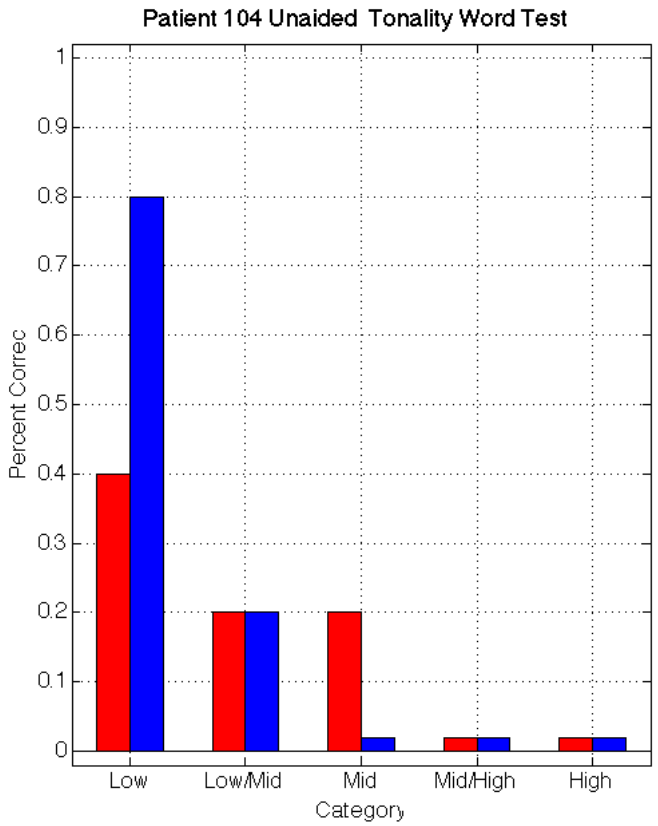
Ear **Left** Conditions: UNAIDED at 6 feet

Low			Low-Middle			Middle			Middle-High			High		
	Score	Error		*Score*	Error		*Score*	Error		*Score*	Error		*Score*	Error
blue	+		**boat**	+		**hot**	- - -		**tie**	- - +		**itch**	- - -	it
no	+		**good**	- - -	did	**cat**	- - -		**kit**	- - -	hit	**see**	- - -	sue
row	+		**comb**	- +		**knock**	- - +		**kite**	- - +		**she**	- - -	–
prune	- - -	clean	**top**	- - -	–	**top**	- - -	pop	**jet**	- - -	yet	**cease**	- - -	choose
pull	+		**up**	- - -	–	**tack**	- - -		**ice**	- - -	–	**teach**	- - -	each
80 %			0.2 %			0 %			0 %			0 %		

1st Presentation 20% 2nd Presentation 4% Total 20% Comments:

Comparing the Word Test Score to an Audiogram





Aided Tonality Word Test

Patient: 104

Ear **Right** Conditions: AIDED at 12 feet

Low			Low-Middle			Middle			Middle-High			High		
	Score	Error		*Score*	Error		*Score*	Error		*Score*	Error		*Score*	Error
blue	+		boat	+		hot	+		tie	+		itch	+	
no	+		good	+		cat	+		kit	+		see	+	
row	+		comb	+		knock	+		kite	+		she	+	
prune	+		top	+		top	+		jet	+		cease	+	
pull	+		up	+		tack	+		ice	+		teach	+	
100% %			100% %			100% %			100 %			100 %		

t Presentation 100% 2nd Presentation 0% Total 100% Comments:

Ear **Left** Conditions: AIDED at 12 feet

Low			Low-Middle			Middle			Middle-High			High		
	Score	Error		*Score*	Error		*Score*	Error		*Score*	Error		*Score*	Error
blue	+		boat	+		hot	+		tie	+		itch	+	
no	+		good	+		cat	+		kit	+		see	+	
row	+		comb	+		knock	+		kite	+		she	+	
prune	+		top	+		top	+		jet	+		cease	+	
pull	+		up	+		tack	+		ice	+		teach	+	
100 %			100 %			100 %			100 %			100 %		

t Presentation 100% 2nd Presentation 0% Total 100% Comments:

Parameters for a Successful Fit

- Comfortable fit
  - Earmold comfort
  - Venting for sound quality
- Comfort for Environmental sounds
  - Realistic sound placement (i.e. soft, normal, and loud sounds)
- Preserve perception of speech sounds in various settings

Summary

- The tonality words are a powerful diagnostic tool.

  They measure the effect the damaged ear has on the perception of specific frequencies.

- The tonality words assess the settings of a hearing aid on the perception of different categories of words.
- The tonality word test is an assessment of perception vs. detection.
  - An audiogram and a set of test scores typically agree, but do not always agree.