EMI GTEM Dipole Data and Analysis -
Delta, Environ and Starkey measurement comparisons

ANSI C63.19 WG3 Meeting
April 20th, 2009

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HIA/Starkey Laboratories, Inc.

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Goals

- Environ Labs Dipole versus GTEM Study Overview
  - Objectives
  - Results of Study
  - Real world confirmation
  - Beyond 2.5 GHz
  - Uncertainty

Objectives

- Replicate the Delta study results via independent lab
- Determine immunity ratings for all nine hearing aids (ANSI C63.19 Dipole and GTEM approach)
- Solidify correction factor for the ANSI GTEM categories
- Compare an actual GTEM vs ANSI real world measurement discrepancy
- Present immunity data beyond 2.5 GHz
- Uncertainty both for GTEM and Dipole tests

Results of the Study

Measurement and analysis was carried out on 9 hearing aids. The comparison in test methods was restricted to the E-field.

Input Related Interference Level (IRIL) was measured while applying a fixed field strength according to the ANSI C63.19 dipole antenna method and the IEC 60118-13 TEM cell method. The hearing aid was positioned for maximum response from the dipole antenna according to Paragraphs 5.3.5 and 5.3.6 of ANSI C63.19 and for maximum response in the GTEM according to Paragraph 7.5 of IEC 60118-13.

The maximum IRIL level found by the ANSI C63.19 method and the maximum from the IEC 60118-13 method was used as the comparison point between the two test methods.

The results of the frequency scans were normalized at the point of comparison by rescaling the field strength to the level that generates an IRIL of 55 dB SPL. It was assumed that the hearing aid was linear during extrapolation and that it followed the “dB V/m:dB SPL” relationship of “1:2”.

Results of the Study

The normalized field strength levels in pairs, for the 9 hearing aids, were plotted in a scatter plot in Figure 1. The X-axis of the plot gives the IEC 60118-13 field strength value, while the Y-axis gives the field strength value of the same unit during the ANSI C63.19 test.

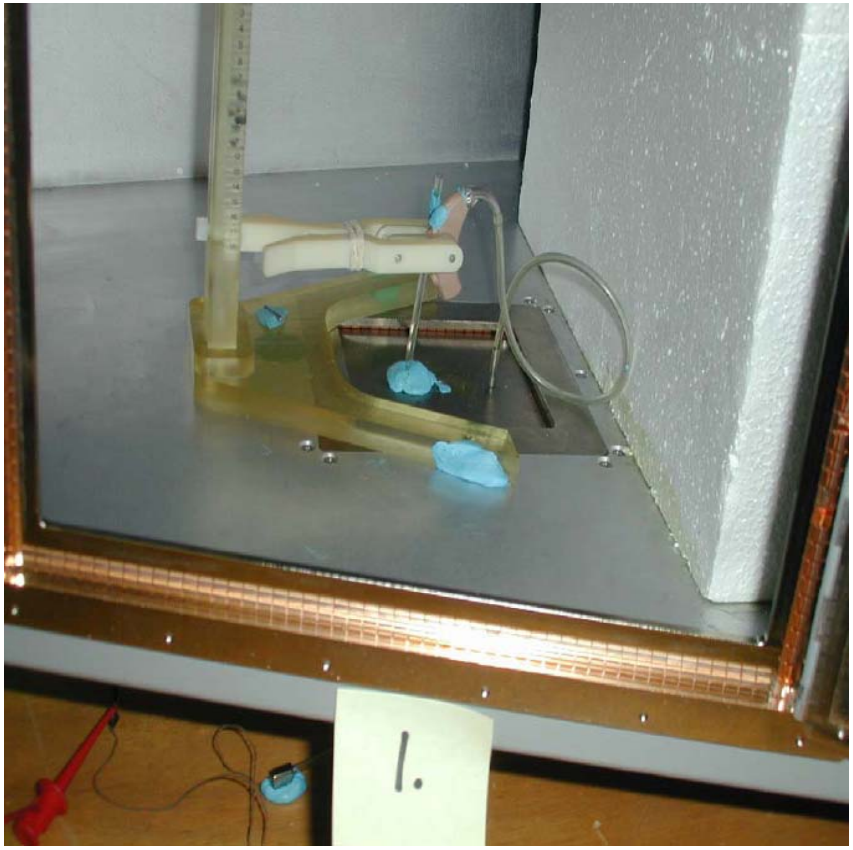
Based on to the Trend Line of Figure 1, the IEC 60118-13 test method required between 4.5 dB and 14.5 dB less field than the ANSI C63.19 test method to produce an IRIL level of 55 dB SPL.

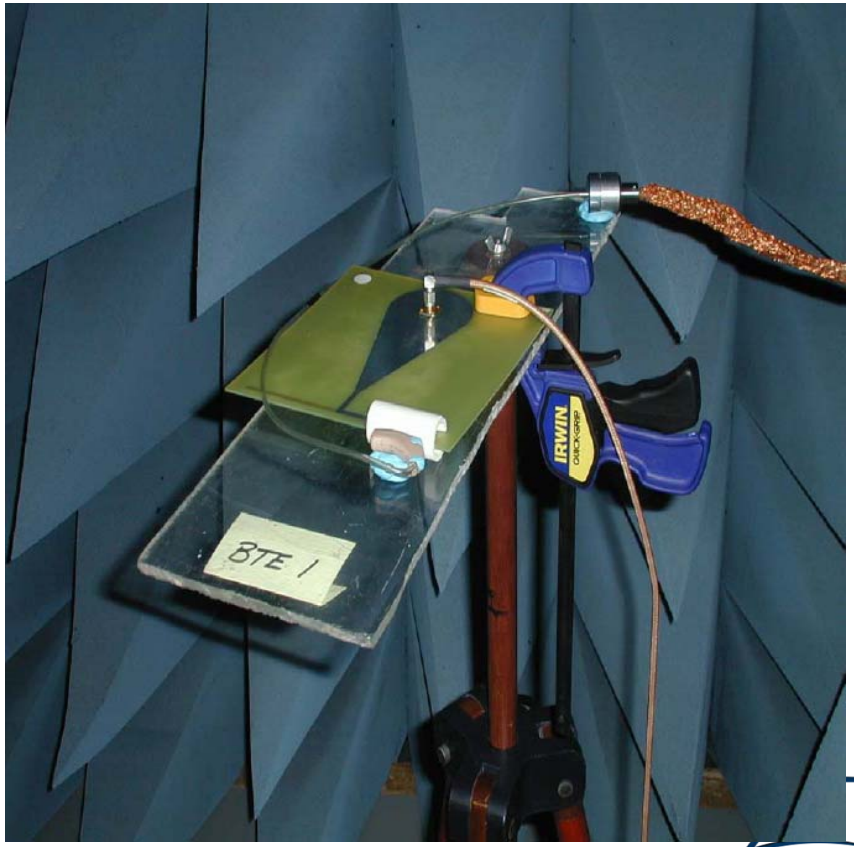
Test results would suggest reducing the ANSI C63.19 test field strength levels by 10 dB when testing is to be carried out in a TEM cell. This would harmonize the IEC and ANSI standards at the ANSI category M3/T3 level.

Product Tested

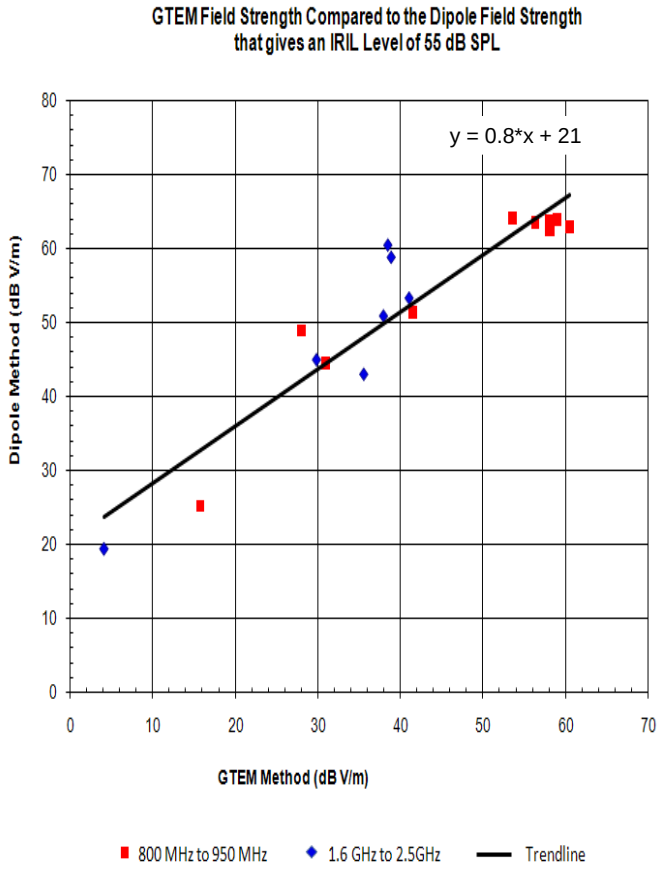
Manufacturer	Starkey Laboratories, Inc.
Device	Hearing Aids
Model/Part Number	Confidential
Serial Number	BTE1, BTE2, BTE3, BTE4, BTE5, BTE6, ITE7, ITE8, and ITE9

Dipole and GTEM Configurations

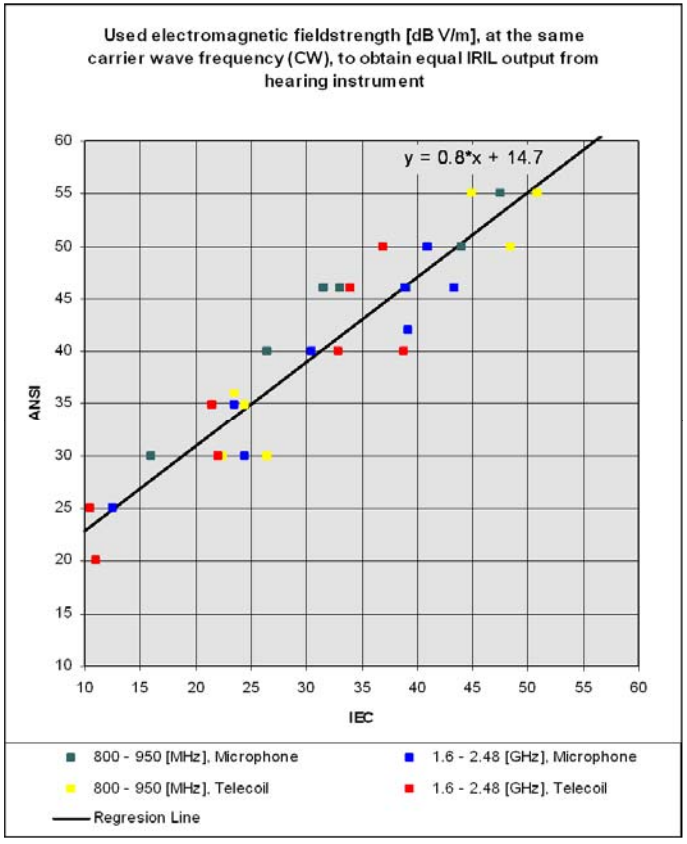




GTEM vs. Dipole



Environ Study



DELTA Study

7 to 10 dB difference between GTEM and Dipole, GTEM more aggressive with current categories

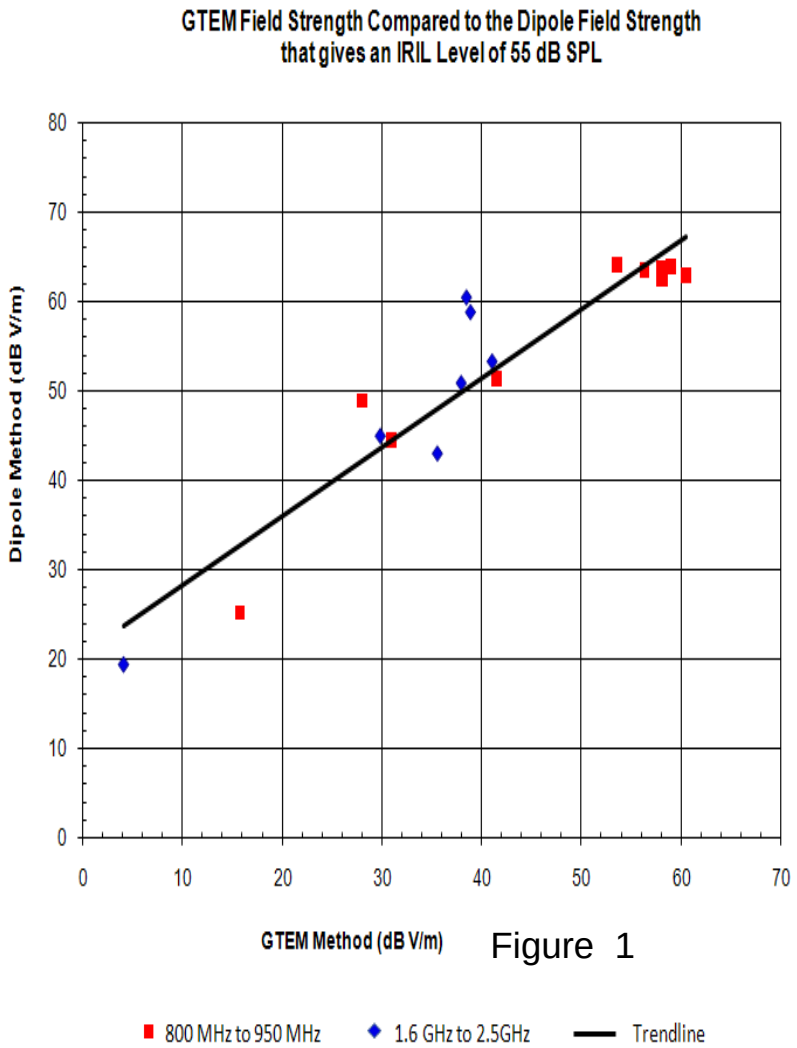


Figure 1

Environ Study

$y = 0.8*x + 21$

COMPANY: Starkey Laboratories, Inc. SPEC: IEC 60118.13 / ANSI C63.19 SECTION: 7 / 5

DEVICE: Hearing Aid MODEL NO.: Confidential SERIAL NO.: BTE 1

TEST DESCRIPTION: Radiated Radio Frequency (RF) Susceptibility, Comparison Study Test Location: Chamber 2

Table 1: Radiated RF Susceptibility Test Results

Frequency Range	Test Method	Modulation	Mode	Test Level	Frequency of Max Response (Fmax)	IRIL at Fmax	Field Strength at Fmax Where IRIL = 55 dB SPL	Notes	
800 MHz to 950 MHz	IEC 60118-13, 0° Orientation	1 kHz, 80% AM	Acoustic	105.6 V/m	901.46 MHz	16.6 dB SPL	887 V/m, Calculated, Measured 27 dB SPL at 177 V/m	Figure 2	
800 MHz to 950 MHz	IEC 60118-13, 90° Orientation	1 kHz, 80% AM	Acoustic	105.4 V/m	947.44 MHz	13.8 dB SPL	1986 V/m, Calculated, Measured 13 dB SPL at 177 V/m	Figure 3	M4
800 MHz to 950 MHz	IEC 60118-13, 180° Orientation	1 kHz, 80% AM	Acoustic	106.1 V/m	866.29 MHz	18.9 dB SPL	1042 V/m, Calculated, Measured 24 dB SPL at 175 V/m	Figure 4	
800 MHz to 950 MHz	IEC 60118-13, 270° Orientation	1 kHz, 80% AM	Acoustic	102.8 V/m	938.06 MHz	11.8 dB SPL	2228 V/m, Calculated, Measured 11 dB SPL at 177 V/m	Figure 5	
1.6 GHz to 2.5 GHz	IEC 60118-13, 0° Orientation	1 kHz, 80% AM	Acoustic	51.3 V/m	2.07 GHz	60.0 dB SPL	47 V/m, Calculated, Measured 56 dB SPL at 50 V/m	Figure 6	
1.6 GHz to 2.5 GHz	IEC 60118-13, 90° Orientation	1 kHz, 80% AM	Acoustic	52.7 V/m	1.93 GHz	69.5 dB SPL	35 V/m, Calculated, Measured 58 dB SPL at 42 V/m	Figure 7	
1.6 GHz to 2.5 GHz	IEC 60118-13, 180° Orientation	1 kHz, 80% AM	Acoustic	52.7 V/m	2.50 GHz	55.1 dB SPL	53 V/m, Measured, Measured 55 dB SPL at 53 V/m	Figure 8	M1
1.6 GHz to 2.5 GHz	IEC 60118-13, 270° Orientation	1 kHz, 80% AM	Acoustic	51.8 V/m	1.97 GHz	69.4 dB SPL	47 V/m, Calculated, Measured 53 dB SPL at 42 V/m	Figure 9 Measured Compression Delta < 1 dB	
800 MHz to 950 MHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	177.0 V/m	857.71 MHz	16.9 dB SPL	1587 V/m, Calculated, Measured 16.9 dB SPL at 177 V/m	Figure 10	M4
800 MHz to 950 MHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.406 A/m	840.81 MHz	13.6 dB SPL	4.401 A/m, Calculated, Measured 13.6 dB SPL at 0.406 A/m	Figure 11	M4
1.6 GHz to 2.5 GHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	77.1 V/m	2.09 GHz	32.3 dB SPL	169 V/m, Measured, Measured 55 dB SPL at 169 V/m	Figure 12	M3
1.6 GHz to 2.5 GHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.244 A/m	2.09 GHz	34.5 dB SPL	0.759 A/m, Calculated, Measured 43.7 dB SPL at 0.396 A/m	Figure 13	M4

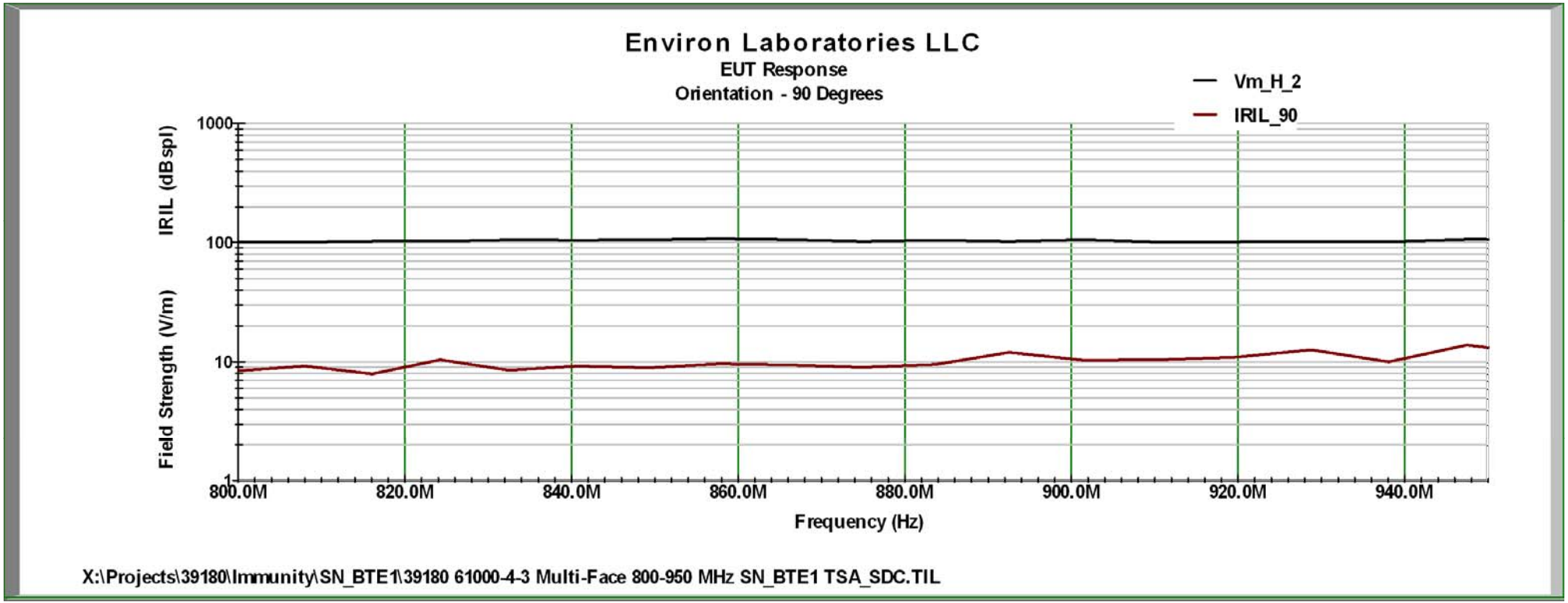


Figure 1: Radiated RF Susceptibility, EUT Audio Output (Red), Field Strength Applied (Black), 800 MHz to 950 MHz, 90 Degree Orientation

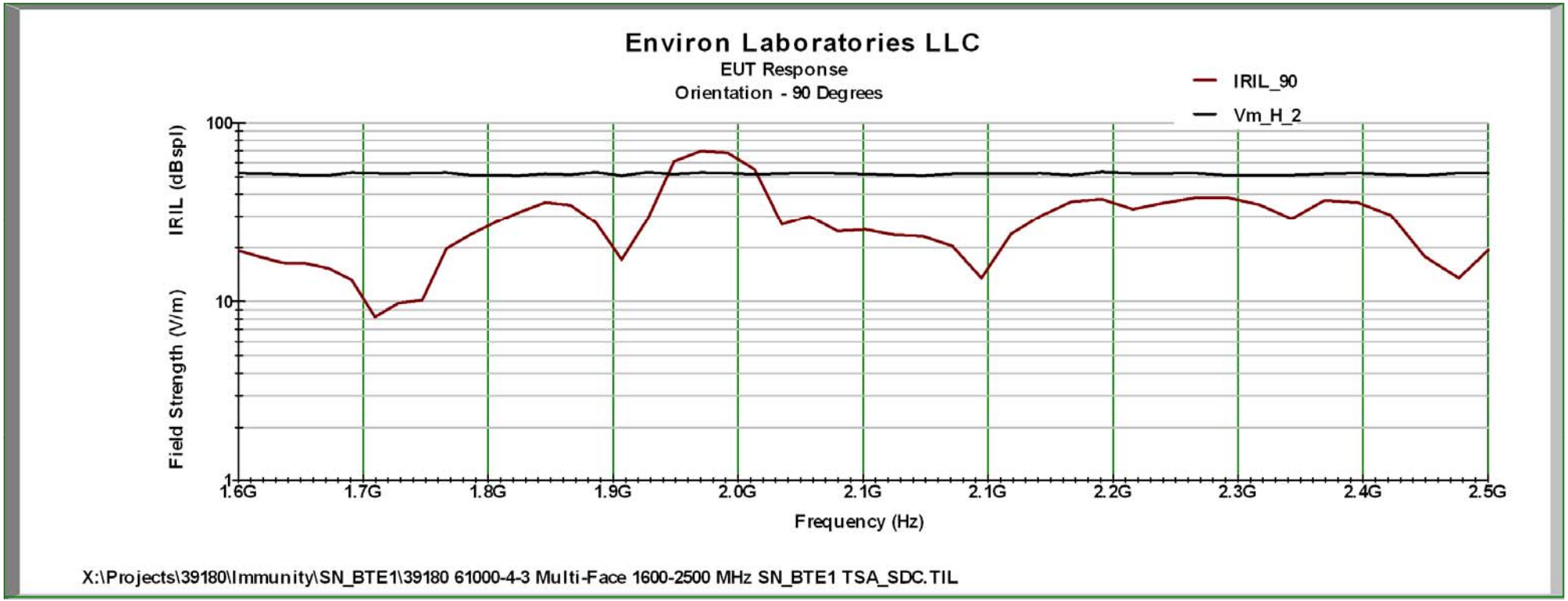


Figure 1: Radiated RF Susceptibility, EUT Audio Output (Red), Field Strength Applied (Black), 1600 MHz to 2500 MHz, 90 Degree Orientation

COMPANY: Starkey Laboratories, Inc. SPEC: IEC 60118.13 / ANSI C63.19 SECTION: 7 / 5

DEVICE: Hearing Aid MODEL NO.: Confidential SERIAL NO.: ITE 8

TEST DESCRIPTION: Radiated Radio Frequency (RF) Susceptibility, Comparison Study Test Location: Chamber 2

Table 1: Radiated RF Susceptibility Test Results

Frequency Range	Test Method	Modulation	Mode	Test Level	Frequency of Max Response (Fmax)	IRIL at Fmax	Field Strength at Fmax Where IRIL = 55 dB SPL	Notes	
800 MHz to 950 MHz	IEC 60118-13, 0 ° Orientation	1 kHz, 80% AM	Acoustic	156 V/m	832.48 MHz	20.0 dB SPL	950 V/m, Calculated, Measured 26 dB SPL at 179 V/m	Figure 2	
800 MHz to 950 MHz	IEC 60118-13, 90° Orientation	1 kHz, 80% AM	Acoustic	150 V/m	950.00 MHz	25.9 dB SPL	1578 V/m, Calculated, Measured 17 dB SPL at 177 V/m	Figure 3	M4
800 MHz to 950 MHz	IEC 60118-13, 270° Orientation	1 kHz, 80% AM	Acoustic	150 V/m	950.00 MHz	26.6 dB SPL	795 V/m, Calculated, Measured 51 dB SPL at 148 V/m	Figure 4 Reached maximum rated input level of GTEM at 148 V/m.	
800 MHz to 950 MHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	181.2 V/m	926.78 MHz	17.8 dB SPL	1540 V/m, Calculated, Measured 17.8 dB SPL at 181 V/m	Figure 10	
800 MHz to 950 MHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.405 A/m	849.22 MHz	17.1 dB SPL	3.589 A/m, Calculated, Measured 17.1 dB SPL at 0.405 A/m	Figure 11	
1.6 GHz to 2.5 GHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	77.1 V/m	2.09 GHz	28.2 dB SPL	351 V/m, Calculated, Measured 43.1 dB SPL at 177 V/m	Figure 12	M1
1.6 GHz to 2.5 GHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.274 A/m	2.09 GHz	25.5 dB SPL	1.675 A/m, Calculated, Measured 29.9 dB SPL at 0.395 A/m	Figure 13	
1.6 GHz to 2.5 GHz	IEC 60118-13, 270° Orientation	1 kHz, 80% AM	Acoustic	150 V/m	950.00 MHz	26.6 dB SPL	795 V/m, Calculated, Measured 51 dB SPL at 148 V/m	Figure 4 Reached maximum rated input level of GTEM at 148 V/m.	
800 MHz to 950 MHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	181.2 V/m	926.78 MHz	17.8 dB SPL	1540 V/m, Calculated, Measured 17.8 dB SPL at 181 V/m	Figure 10	M4
800 MHz to 950 MHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.405 A/m	849.22 MHz	17.1 dB SPL	3.589 A/m, Calculated, Measured 17.1 dB SPL at 0.405 A/m	Figure 11	M4
1.6 GHz to 2.5 GHz	ANSI C63.19, E Field	1 kHz, 80% AM	Acoustic	77.1 V/m	2.09 GHz	28.2 dB SPL	351 V/m, Calculated, Measured 43.1 dB SPL at 177 V/m	Figure 12	M3
1.6 GHz to 2.5 GHz	ANSI C63.19, H Field	1 kHz, 80% AM	Acoustic	0.274 A/m	2.09 GHz	25.5 dB SPL	1.675 A/m, Calculated, Measured 29.9 dB SPL at 0.395 A/m	Figure 13	M4

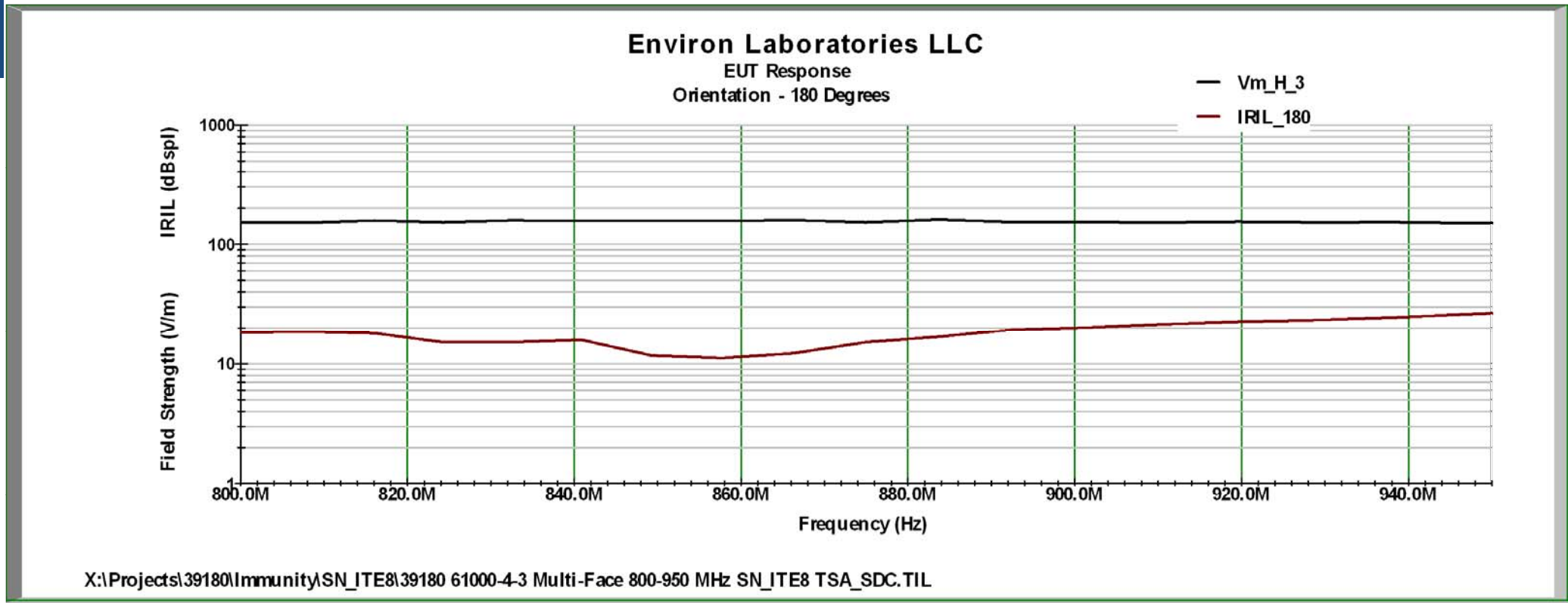


Figure 4: Radiated RF Susceptibility, EUT Audio Output (Red), Field Strength Applied (Black), 800 MHz to 950 MHz, 180 Degree Orientation

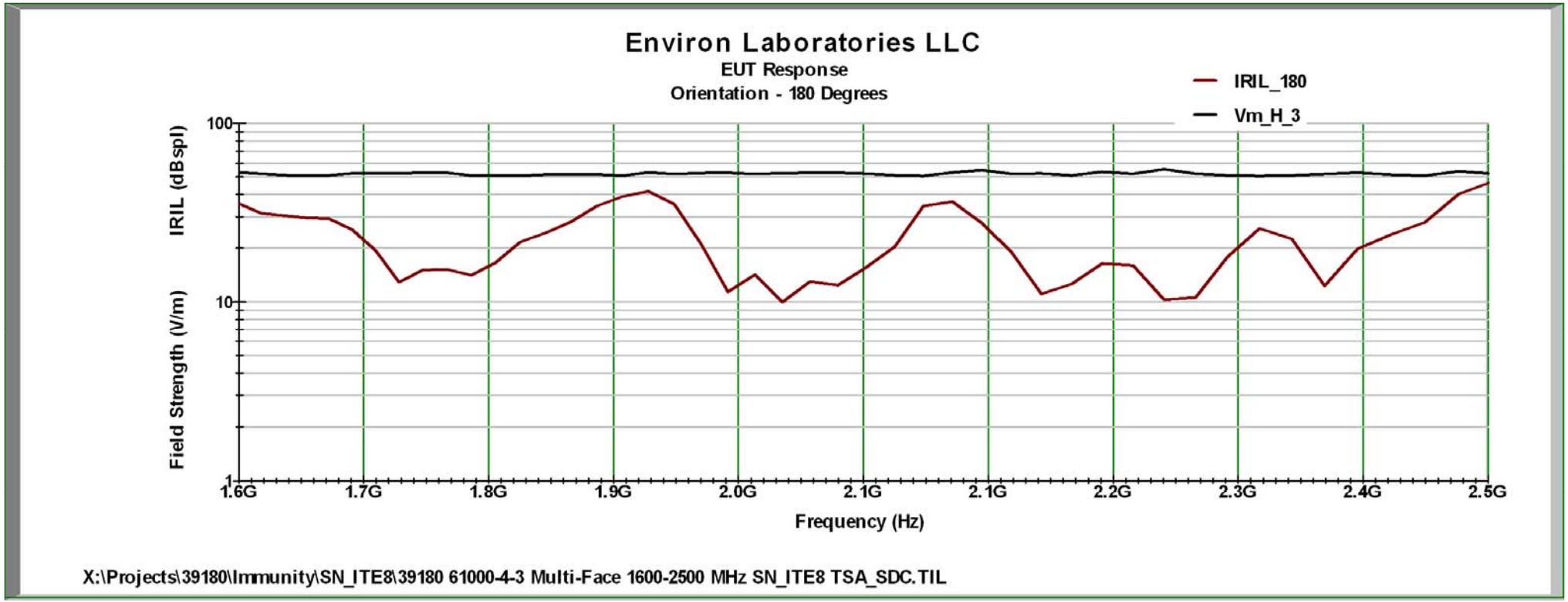


Figure 8: Radiated RF Susceptibility, EUT Audio Output (Red), Field Strength Applied (Black), 1600 MHz to 2500 MHz, 180 Degree Orientation

Current ANSI C63.19 Hearing Aid Near Field (dipole) Categories

Category	Hearing aid RF parameters (hearing aid must maintain < 55 dB IRIL interference level and < 6 dB gain compression)			
Near field	E-field immunity (CW)		H-field immunity (CW)	
Category M1/T1	30.0 to 35.0	dB (V/m)	–23.0 to –18.0	dB (A/m)
Category M2/T2	35.0 to 40.0	dB (V/m)	–18.0 to –13.0	dB (A/m)
Category M3/T3	40.0 to 45.0	dB (V/m)	–13.0 to –8.0	dB (A/m)
Category M4/T4	> 45.0	dB (V/m)	> –8.0	dB (A/m)

Category M1/T1	30.0 to 35.0	dB (V/m)	–23.0 to –18.0	dB (A/m)
Category M2/T2	35.0 to 40.0	dB (V/m)	–18.0 to –13.0	dB (A/m)
Category M3/T3	40.0 to 45.0	dB (V/m)	–13.0 to –8.0	dB (A/m)
Category M4/T4	> 45.0	dB (V/m)	> –8.0	dB (A/m)

Category M1/T1	30.0 to 35.0	dB (V/m)	–23.0 to –18.0	dB (A/m)
Category M2/T2	35.0 to 40.0	dB (V/m)	–18.0 to –13.0	dB (A/m)
Category M3/T3	40.0 to 45.0	dB (V/m)	–13.0 to –8.0	dB (A/m)
Category M4/T4	> 45.0	dB (V/m)	> –8.0	dB (A/m)

Proposed ANSI C63.19 Far Field Hearing Aid (GTEM) Categories

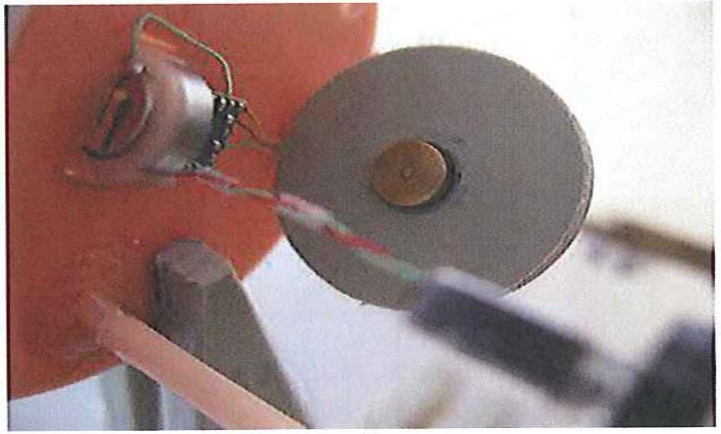
7 dB reduction in the immunity requirements

Category M1/T1	14.1 to 25.1	V/m	0.032 to 0.056	A/m
Category M2/T2	25.2 to 44.7	V/m	0.056 to 0.10	A/m
Category M3/T3	44.7 to 79.4	V/m	0.10 to 0.178	A/m
Category M4/T4	> 79.4	V/m	> 0.178	A/m

Category M1/T1	14.1 to 25.1	V/m	0.032 to 0.056	A/m
Category M2/T2	25.2 to 44.7	V/m	0.056 to 0.10	A/m
Category M3/T3	44.7 to 79.4	V/m	0.10 to 0.178	A/m
Category M4/T4	> 79.4	V/m	> 0.178	A/m

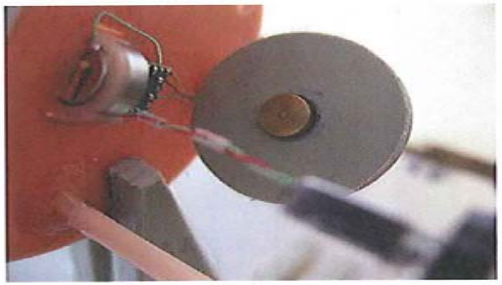
Category	**Hearing aid RF parameters (hearing aid must maintain < 55 dB IRIL interference level and < 6 dB gain compression)**			
Near field	**E-field immunity (CW)**		**H-field immunity (CW)**	
Category M1/T1	23.0 to 28.0	dB (V/m)	–30.0 to –25.0	dB (A/m)
Category M2/T2	28.0 to 33.0	dB (V/m)	–25.0 to –20.0	dB (A/m)
Category M3/T3	33.0 to 38.0	dB (V/m)	–20.0 to –15.0	dB (A/m)
Category M4/T4	> 38.0	dB (V/m)	> –15.0	dB (A/m)

Real world confirmation

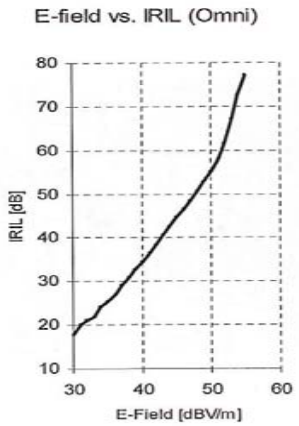


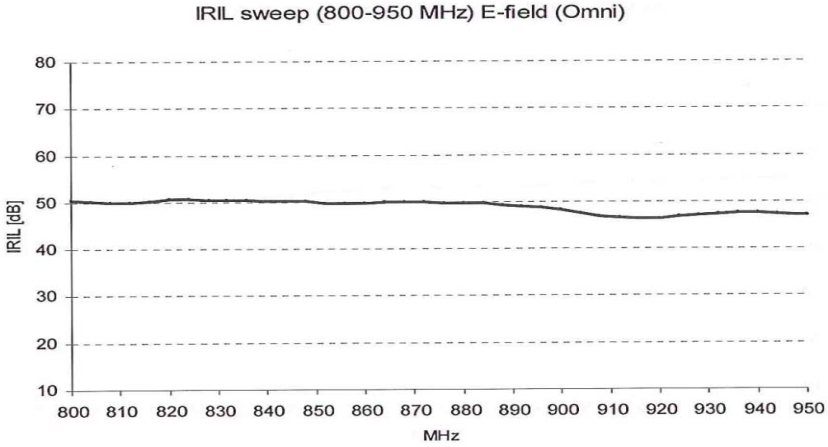
Delta Determining Hot Spots and IRIL Frequency Sweeps - Dipole method

Determining the hotspot



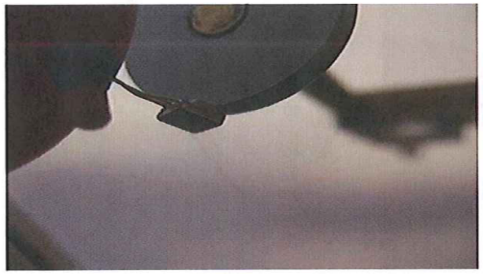
Field Strength vs. IRIL

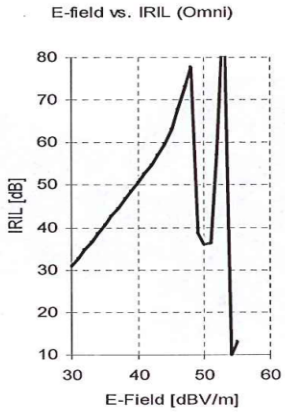


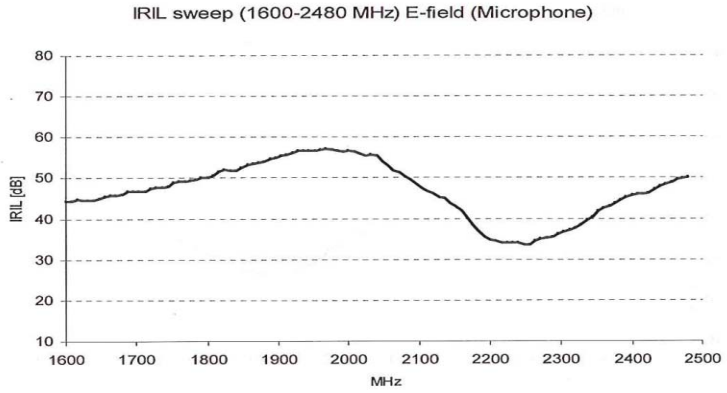


Faceplate #3 Low Band (M4) Input level 48 dB V/m

Delta Determining Hot Spots and IRIL Frequency Sweep – Dipole methods

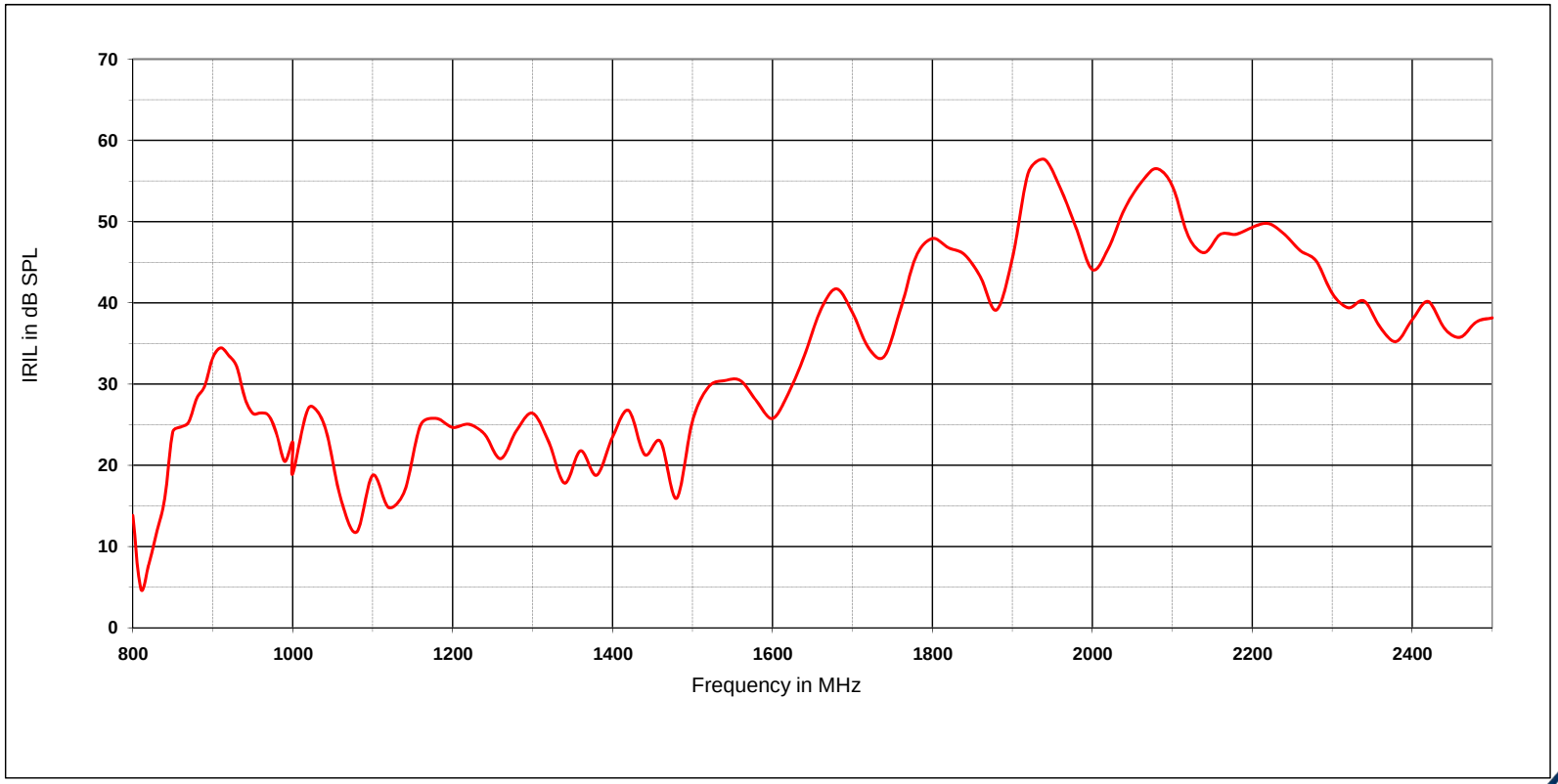






Faceplate #3 High Band (M3) reached 55 dB IRIL with input level 42 dB V/m

Mic wires vertical & receiver wires Horizontal (3-6-08)
Starkey GTEM method



Faceplate #3 (M1) Input at 50 dB V/M

Proposed ANSI C63.19 GTEM Hearing Aid Categories

7 dB reduction in the immunity requirements

Category M1/T1	14.1 to 25.1	V/m	0.032 to 0.056	A/m
Category M2/T2	25.2 to 44.7	V/m	0.056 to 0.10	A/m
Category M3/T3	44.7 to 79.4	V/m	0.10 to 0.178	A/m
Category M4/T4	> 79.4	V/m	> 0.178	A/m

Category M1/T1	14.1 to 25.1	V/m	0.032 to 0.056	A/m
Category M2/T2	25.2 to 44.7	V/m	0.056 to 0.10	A/m
Category M3/T3	44.7 to 79.4	V/m	0.10 to 0.178	A/m
Category M4/T4	> 79.4	V/m	> 0.178	A/m

Category M1/T1	23.0 to 28.0	dB (V/m)	–30.0 to –25.0	dB (A/m)
Category M2/T2	28.0 to 33.0	dB (V/m)	–25.0 to –20.0	dB (A/m)
Category M3/T3	33.0 to 38.0	dB (V/m)	–20.0 to –15.0	dB (A/m)
Category M4/T4	> 38.0	dB (V/m)	> –15.0	dB (A/m)

Category M1/T1	23.0 to 28.0	dB (V/m)	–30.0 to –25.0	dB (A/m)
Category M2/T2	28.0 to 33.0	dB (V/m)	–25.0 to –20.0	dB (A/m)
Category M3/T3	33.0 to 38.0	dB (V/m)	–20.0 to –15.0	dB (A/m)
Category M4/T4	> 38.0	dB (V/m)	> –15.0	dB (A/m)

For Faceplate #3 @ a GTEM input of 50 V/m using the revised immunity levels above the Faceplate #3 would achieve an M3 to M4 rating similar to the Dipole method.

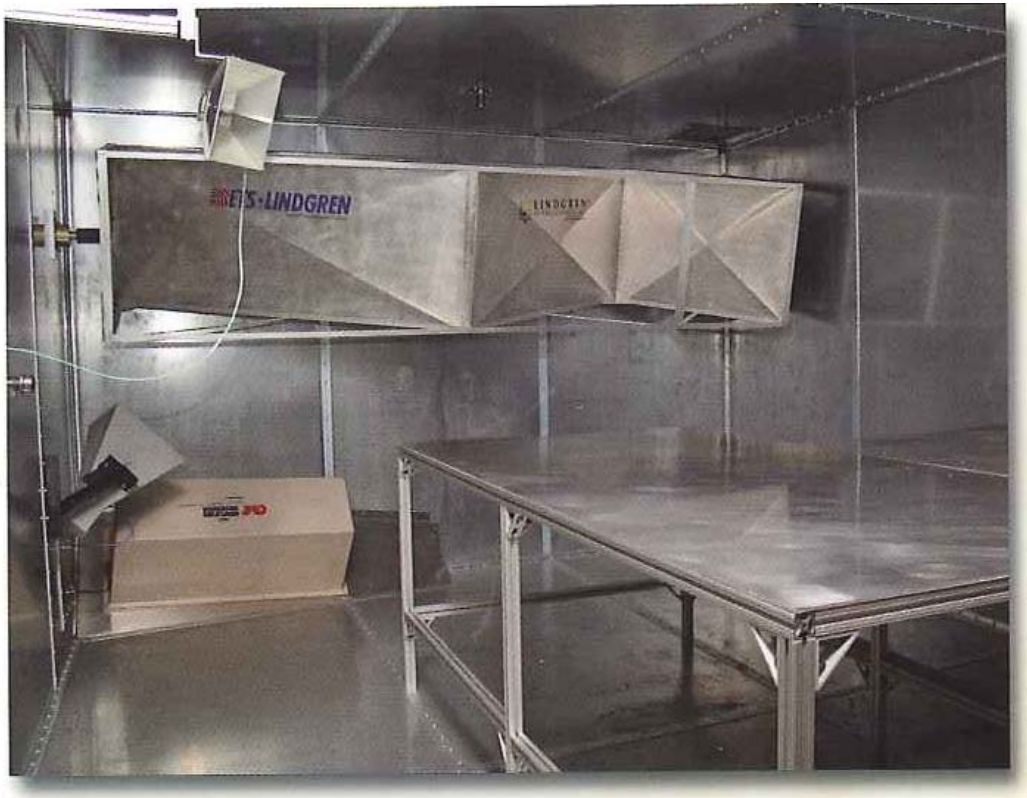
Differences between DELTA (dipole) and Starkey (GTEM)

- The difference is accounted for due to the GTEM being a more aggressive test method.
- The proposed GTEM immunity relief is required in order to better align the Dipole and GTEM results.

Beyond 2.5 GHz

EMI/EMC

- Fully automated testing
- Radiated Susceptibility @ >200 V/m
- Multiple burst / multiple stroke lightning
- HIRF @ >3000 V/m, up to 18 GHz
- Multiple semi-anechoic chambers
- Reverberation chamber
- Power input, capabilities exceeding 300 Amps/300 Volts
- GTEM cell
- FCC/CE Emissions



HIRF/Mode tuned chamber

Beyond 2.5 GHz

EMI tests of Starkey hearing aids done at Environ Labs on 4-13-09

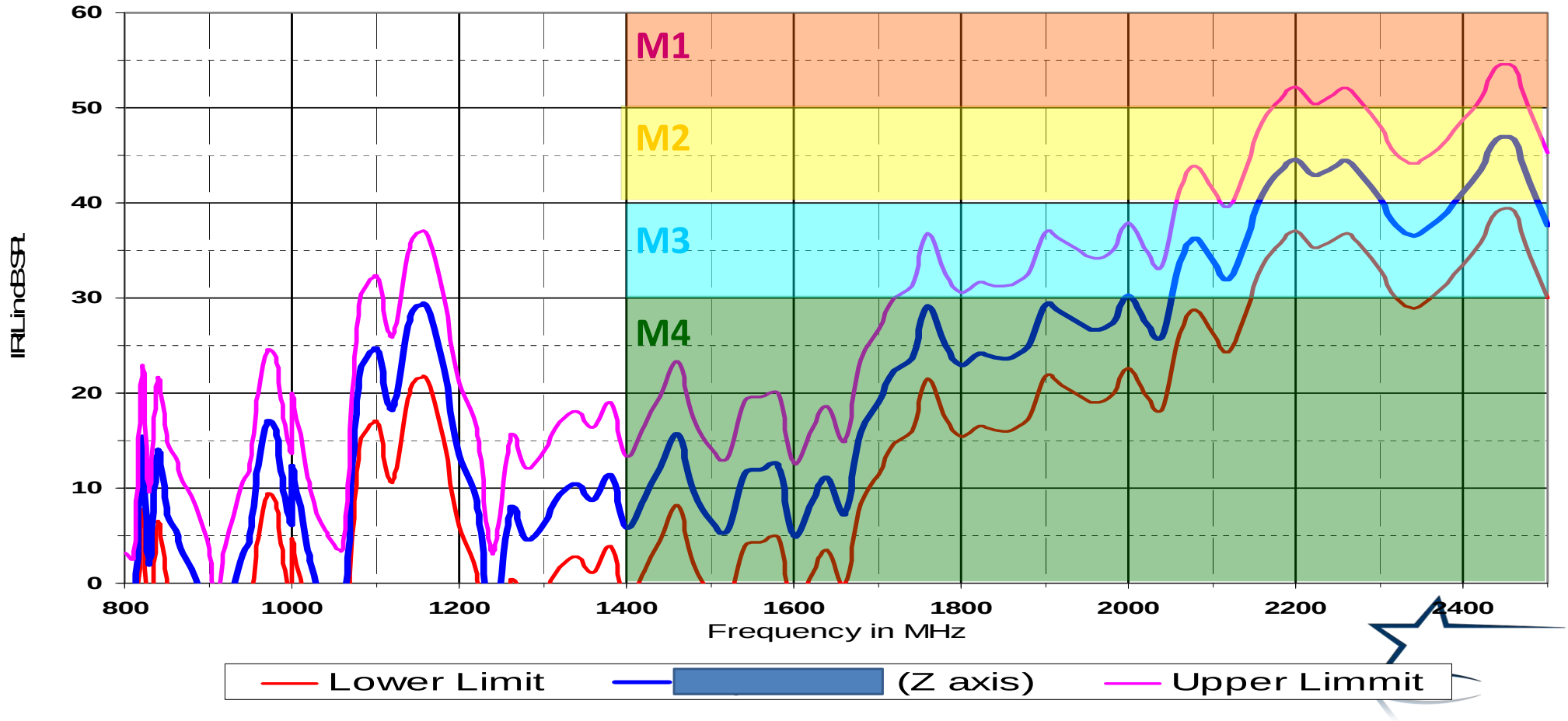
Aids were tested in Environ's reverberent RF room (provides diffuse RF field).
RF room has frequency response of 100 MHz to 18 GHz (their smaller RF room goes from 400 MHz to 40 GHz).

2 hearing aids were tested, from the group of 9 that Environ tested in Nov. 2008 comparing GTEM and dipole methods.
HA # 4: K13 Destiny 1600 BTE # 07-924741 -- I measured max IRIL of 46 dB at 2.06 GHz in our GTEM.
HA # 8: ITC # C1 -- I had measured max IRIL of 37 dB at 2.45 GHz in our GTEM.

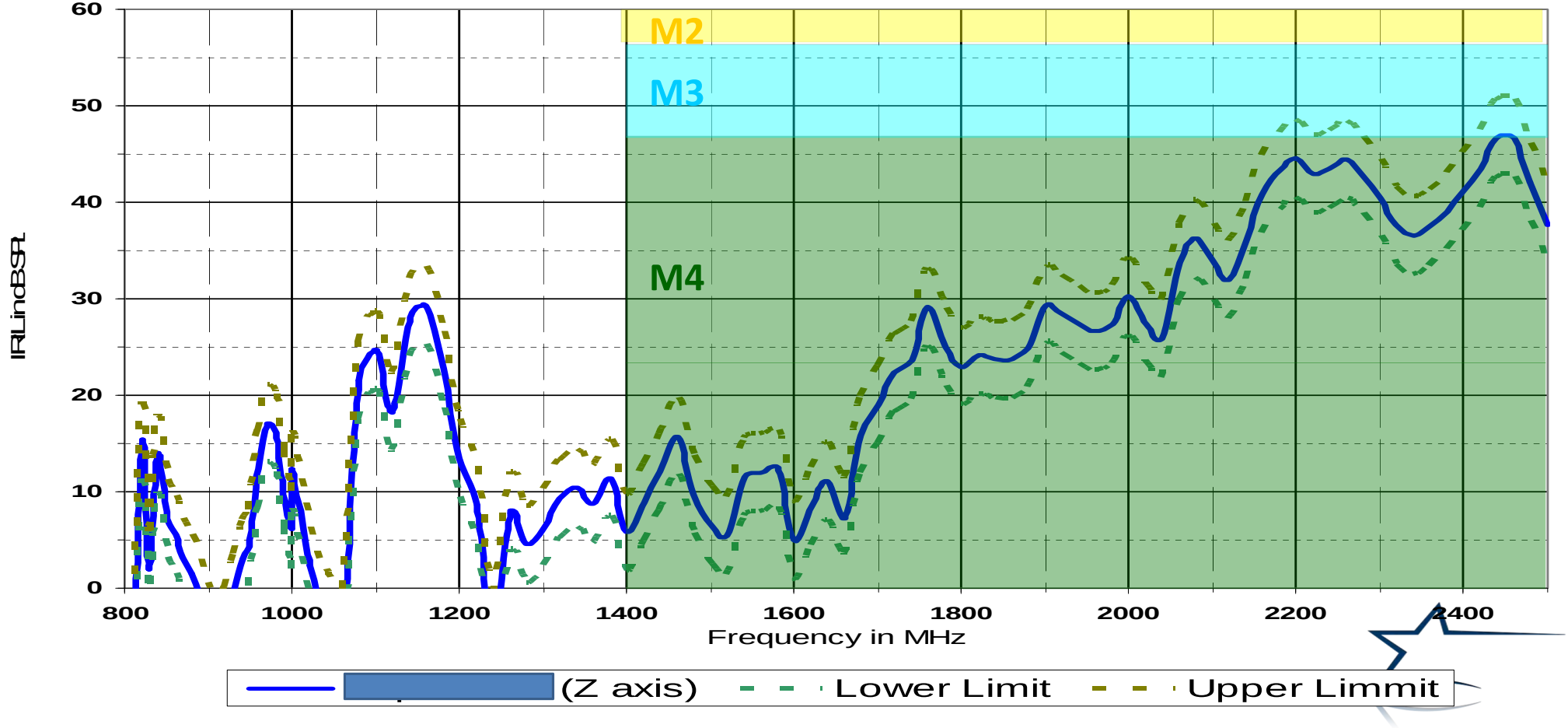
Tests at Environ were done with RF field strength = 50 V/m in the RF room.
20" of plastic tubing went from hearing aid to 2cc coupler. (Coupler was outside of RF room.)

HA tested	HA orientation	Freq. Range	Max IRIL	M rating
# 4 BTE	Z axis vertical	1.6 - 2.0 GHz	34 dB	M3
"	X axis vertical	"	37	"
"	Y axis vertical	"	34	"
"	"	2.0 - 4.0	34.5	"
# 8 ITC	Y axis vertical	1.0 - 2.0 GHz	31.5 dB	M4
"	X or Z axis vertical	1.6 - 2.0	30	M4
"	"	2.0 - 2.5	42.6	M3
"	"	2.0 - 4.0	47.3	M2

Measurement Uncertainty Using Delta's Dipole Setup



Measurement Uncertainty Using Delta's GTEM Setup



Thank You !