

Appendix B: Tissue Stimulating Liquids, System Checks and System Validation

B.1. SAR System Check

Prior to SAR assessment, the system is verified to $\pm 10\%$ of the SAR measurement on the reference dipole at the time of calibration by the calibration facility. Full system validation status and result summary can be found in Section B.3.

Table 1 System Check Results (SAR)

System	Frequency (MHz)	Tissue Type	Date	Amb. Temp. (°C)	Tissue Temp (°C)	Input Power (dBm)	Verification Source SN	Probe SN	DAE SN	Measured 1g SAR (W/Kg)	1W Target 1g SAR (W/Kg)	1W Normalized 1g SAR (W/Kg)	1g SAR Deviation	Measured 10g SAR (W/Kg)	1W Target 10g SAR (W/Kg)	1W Normalized 10g SAR (W/Kg)	10g SAR Deviation (%)
Beta	13	Head	03/13/2024	21.5	22.4	24.5	1041	7853	1839	0.126	0.457	0.447	-2.17%	0.078	0.281	0.277	-1.51%
Gamma	750	Head	02/19/2024	22.9	21.5	17	1235	7859	1844	0.443	8.690	8.839	1.71%	0.292	5.690	5.826	2.39%
Gamma	835	Head	02/19/2024	22.9	21.5	17	4d311	7859	1844	0.514	9.820	10.256	4.44%	0.336	6.370	6.704	5.24%
Gamma	835	Head	02/21/2024	23.5	21.5	17	4d311	7859	1844	0.517	9.820	10.316	5.05%	0.338	6.370	6.744	5.87%
Beta	1750	Head	02/19/2024	22.7	22.2	17	1205	7836	1839	1.740	36.500	34.718	-4.88%	0.925	19.200	18.456	-3.87%
Beta	1750	Head	02/21/2024	23.1	22	17	1205	7836	1839	1.740	36.500	34.718	-4.88%	0.922	19.200	18.396	-4.19%
Beta	1900	Head	02/19/2024	22.7	22.2	17	5d252	7836	1839	1.990	39.800	39.706	-0.24%	1.030	21.000	20.551	-2.14%
Beta	1900	Head	02/21/2024	23.1	22	17	5d252	7836	1839	1.980	39.800	39.506	-0.74%	1.020	21.000	20.352	-3.09%
Delta	2450	Head	02/21/2024	23.1	20.8	17	1112	7857	1843	2.450	51.800	48.884	-5.63%	1.140	24.400	22.746	-6.78%
Delta	2450	Head	03/04/2024	23.1	21.3	17	1112	7857	1843	2.450	51.800	48.884	-5.63%	1.140	24.400	22.746	-6.78%
Delta	2600	Head	02/19/2024	23.1	21.1	17	1215	7857	1843	2.600	57.200	51.877	-9.31%	1.170	25.800	23.345	-9.52%
Beta	5250	Head	02/28/2024	23.4	21.5	17	1396	7836	1839	3.660	81.000	73.027	-9.84%	1.060	23.000	21.150	-8.04%
Beta	5250	Head	03/11/2024	22.5	21.9	17	1396	7836	1839	3.710	81.000	74.024	-8.61%	1.060	23.000	21.150	-8.04%
Beta	5600	Head	02/28/2024	23.4	21.5	17	1396	7836	1839	4.090	83.800	81.606	-2.62%	1.160	23.900	23.145	-3.16%
Beta	5600	Head	03/11/2024	22.5	21.9	17	1396	7836	1839	3.940	83.800	78.613	-6.19%	1.110	23.900	22.147	-7.33%
Beta	5750	Head	02/28/2024	23.4	21.5	17	1396	7836	1839	3.700	81.100	73.825	-8.97%	1.060	22.900	21.150	-7.64%

B.2. Dielectric Parameters of the TSL

Table 2 SAR Tissue Dielectric Parameters

Date	Tissue Type	Liquid Temp (°C)	Frequency (MHz)	Conductivity Measured (σ)	Conductivity Target (σ)	Deviation	Permittivity measured (ε _r)	Permittivity Target (ε _r)	Deviation
2/19/2024	Head	22.2	1710	1.35	1.35	-0.06%	39.2	40.1	-2.29%
2/19/2024	Head	22.2	1750	1.37	1.37	0.15%	39.1	40.1	-2.36%
2/19/2024	Head	22.2	1790	1.40	1.39	0.15%	39.1	40.0	-2.36%
2/19/2024	Head	22.2	1850	1.43	1.40	2.20%	38.9	40.0	-2.72%
2/19/2024	Head	22.2	1880	1.45	1.40	3.35%	38.9	40.0	-2.79%
2/19/2024	Head	22.2	1900	1.46	1.40	4.06%	38.8	40.0	-2.88%
2/19/2024	Head	22.2	1920	1.47	1.40	4.96%	38.8	40.0	-3.01%
2/19/2024	Head	21.8	680	0.87	0.89	-1.62%	42.9	42.3	1.58%
2/19/2024	Head	21.8	695	0.88	0.89	-1.02%	42.9	42.2	1.56%
2/19/2024	Head	21.8	710	0.88	0.89	-0.40%	42.8	42.1	1.55%
2/19/2024	Head	21.8	750	0.90	0.89	0.33%	42.6	41.9	1.66%
2/19/2024	Head	21.8	770	0.90	0.89	1.03%	42.6	41.8	1.89%
2/19/2024	Head	21.8	785	0.91	0.89	1.45%	42.6	41.7	1.96%
2/19/2024	Head	21.8	800	0.91	0.90	1.87%	42.5	41.7	1.97%
2/19/2024	Head	21.8	815	0.92	0.90	2.61%	42.5	41.6	2.08%
2/19/2024	Head	21.8	835	0.93	0.90	3.15%	42.4	41.5	2.21%
2/19/2024	Head	21.8	850	0.93	0.92	1.82%	42.4	41.5	2.13%
2/19/2024	Head	21.5	2600	1.97	1.96	0.11%	39.0	39.0	-0.09%
2/19/2024	Head	21.5	2650	2.00	2.02	-0.75%	38.9	38.9	-0.18%
2/19/2024	Head	21.5	2680	2.03	2.05	-0.93%	38.8	38.9	-0.19%
2/19/2024	Head	21.5	2700	2.04	2.07	-1.34%	38.8	38.9	-0.24%
2/21/2024	Head	21.6	815	0.93	0.90	4.13%	41.9	41.6	0.84%
2/21/2024	Head	21.6	835	0.94	0.90	4.60%	41.9	41.5	0.96%
2/21/2024	Head	21.6	850	0.95	0.92	3.24%	41.9	41.5	0.86%
2/21/2024	Head	22	1710	1.34	1.35	-0.22%	38.8	40.1	-3.28%
2/21/2024	Head	22	1750	1.37	1.37	-0.13%	38.8	40.1	-3.20%
2/21/2024	Head	22	1790	1.39	1.39	-0.17%	38.7	40.0	-3.21%
2/21/2024	Head	22	1850	1.43	1.40	1.94%	38.6	40.0	-3.46%
2/21/2024	Head	22	1880	1.44	1.40	3.12%	38.6	40.0	-3.54%
2/21/2024	Head	22	1900	1.45	1.40	3.87%	38.5	40.0	-3.64%
2/21/2024	Head	22	1920	1.47	1.40	4.78%	38.5	40.0	-3.74%
2/21/2024	Head	21	2400	1.81	1.76	2.97%	39.9	39.3	1.67%
2/21/2024	Head	21	2450	1.85	1.80	2.63%	39.9	39.2	1.70%
2/21/2024	Head	21	2480	1.87	1.83	2.13%	39.8	39.2	1.67%
2/28/2024	Head	21.5	5150	4.29	4.60	-6.85%	34.6	36.0	-4.12%
2/28/2024	Head	21.5	5200	4.34	4.66	-6.71%	34.5	36.0	-4.18%
2/28/2024	Head	21.5	5250	4.39	4.71	-6.63%	34.4	35.9	-4.30%
2/28/2024	Head	21.5	5300	4.45	4.76	-6.54%	34.3	35.9	-4.34%
2/28/2024	Head	21.5	5350	4.50	4.81	-6.48%	34.2	35.8	-4.50%
2/28/2024	Head	21.5	5500	4.65	4.96	-6.28%	34.0	35.6	-4.65%
2/28/2024	Head	21.5	5550	4.70	5.01	-6.19%	33.9	35.6	-4.77%
2/28/2024	Head	21.5	5600	4.76	5.07	-6.04%	33.8	35.5	-4.85%
2/28/2024	Head	21.5	5650	4.81	5.12	-5.91%	33.7	35.5	-4.96%
2/28/2024	Head	21.5	5700	4.87	5.17	-5.72%	33.6	35.4	-5.05%
2/28/2024	Head	21.5	5750	4.92	5.22	-5.67%	33.5	35.4	-5.11%
2/28/2024	Head	21.5	5800	4.98	5.27	-5.47%	33.5	35.3	-5.21%
3/4/2024	Head	21.6	2400	1.74	1.76	-0.83%	36.5	39.3	-6.99%
3/4/2024	Head	21.6	2450	1.78	1.80	-1.33%	36.5	39.2	-6.95%
3/4/2024	Head	21.6	2480	1.80	1.83	-1.83%	36.4	39.2	-7.02%
3/11/2024	Head	21.8	5150	4.43	4.60	-3.68%	36.5	36.0	1.25%
3/11/2024	Head	21.8	5200	4.49	4.66	-3.53%	36.4	36.0	1.19%
3/11/2024	Head	21.8	5250	4.55	4.71	-3.41%	36.3	35.9	1.06%
3/11/2024	Head	21.8	5300	4.60	4.76	-3.32%	36.2	35.9	1.03%
3/11/2024	Head	21.8	5350	4.65	4.81	-3.21%	36.1	35.8	0.89%
3/11/2024	Head	21.8	5500	4.82	4.96	-2.97%	35.9	35.6	0.73%
3/11/2024	Head	21.8	5550	4.87	5.01	-2.85%	35.8	35.6	0.61%
3/11/2024	Head	21.8	5600	4.93	5.07	-2.69%	35.7	35.5	0.54%
3/11/2024	Head	21.8	5650	4.99	5.12	-2.53%	35.6	35.5	0.44%
3/11/2024	Head	21.8	5700	5.05	5.17	-2.33%	35.5	35.4	0.33%
3/11/2024	Head	21.8	5750	5.10	5.22	-2.28%	35.5	35.4	0.30%
3/11/2024	Head	21.8	5800	5.16	5.27	-2.03%	35.4	35.3	0.19%
3/11/2024	Head	21.8	5850	5.21	5.32	-2.05%	35.3	35.3	0.12%
3/13/2024	Head	23.2	12	0.73	0.75	-3.19%	53.6	55.0	-2.46%
3/13/2024	Head	23.2	13	0.73	0.75	-3.18%	53.8	55.0	-2.27%
3/13/2024	Head	23.2	14	0.73	0.75	-3.15%	53.7	55.0	-2.44%

The above measured tissue parameters were used in the DASY software. The DASY software was used to perform interpolation to determine the dielectric parameters at the SAR test device frequencies (per KDB Publication 865664 D01v01r04 and IEEE 1528-2013 6.6.1.2). The tissue parameters listed in the SAR test plots may slightly differ from the table above due to significant digit rounding in the software.

The SAR values were compensated for deviations between the measured and required tissue dielectric properties, as described in IEEE 1528-2013. The SAR values were applied to only scale up the measured SAR values, and not downward, per KDB Publication 865664 D01v04r04.

B.3. System Validation

Per FCC KDB Publication 865664 D02 Section 2.3 a) states “SAR system validation status and system verification results should be documented in a separate section of the SAR report, or as an attachment, to confirm measurement accuracy.”

The SAR systems used for evaluating this device were validated against its performance specifications prior to the SAR measurements.

Reference dipoles were used with the required tissue-equivalent media for system validation, according to the procedures outlined in FCC KDB Publication 865664 D01 and IEEE 1528-2013. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point.

Per FCC KDB 865664 D02, “the validation status should be documented according to the validation date(s), measurement frequencies, SAR probes, calibrated signal type(s) and tissue dielectric parameters.” A tabulated summary of the system validation status is provided accordingly:

Table 3 System Validation

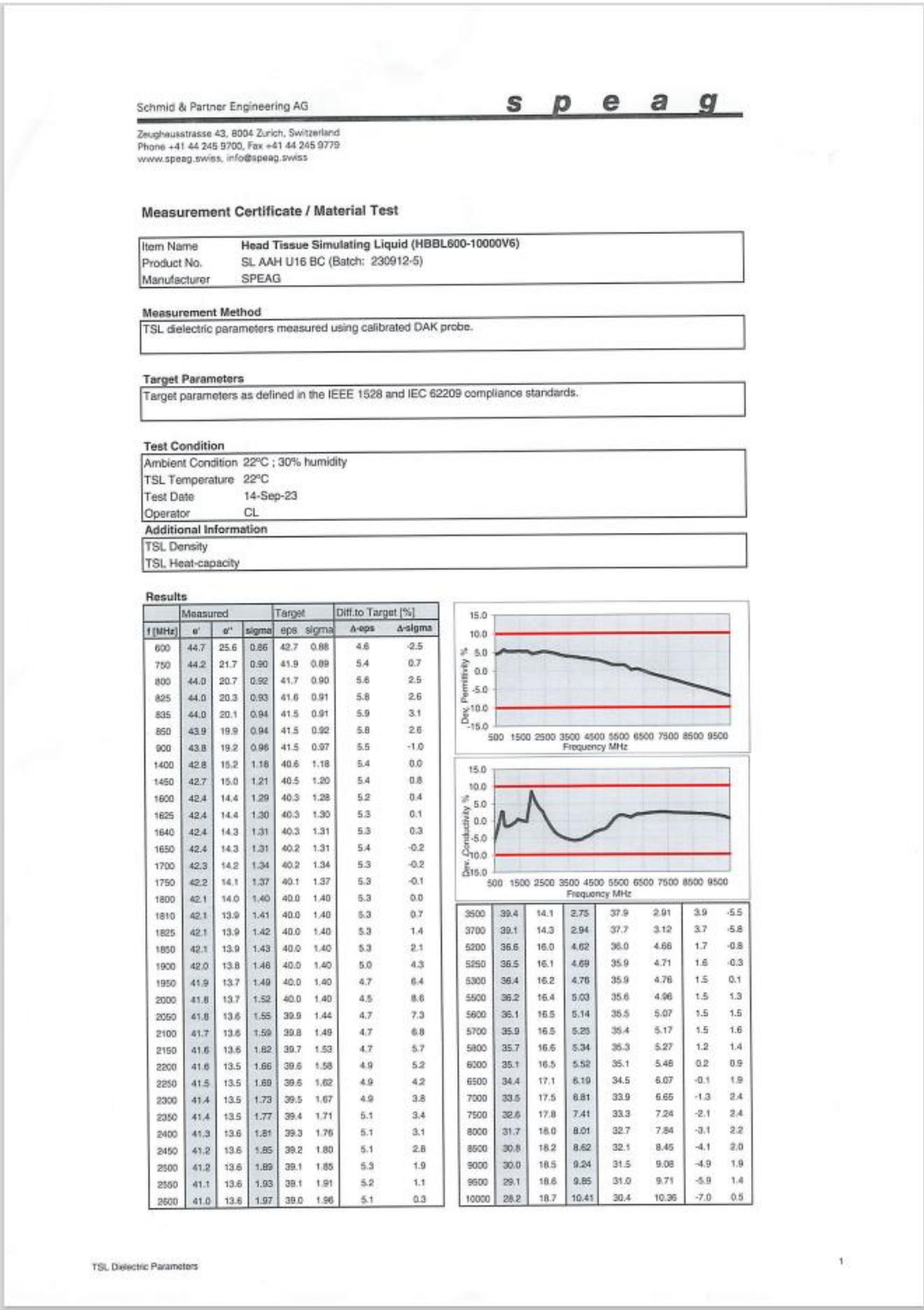
System	Frequency (MHz)	Date	Probe	DAE	Probe CalF		Cond. (σ)	Perm (ϵ_r)	CW Validation			Mod Validation		
					Freq (MHz)	Tissue Type			Sensitivity	Probe Linearity	Probe Isotropy	Mod Type	Duty Factor	PAR
Beta	13	03/07/2024	7853	1839	13	Head	0.745	54.2	PASS	PASS	PASS	N/A	N/A	N/A
Gamma	750	01/15/2024	7859	1844	750	Head	0.888	42.5	PASS	PASS	PASS	N/A	N/A	N/A
Gamma	835	01/29/2024	7859	1844	835	Head	0.921	41.6	PASS	PASS	PASS	GMSK	PASS	N/A
Beta	1750	11/17/2023	7836	1839	1750	Head	1.33	39.9	PASS	PASS	PASS	N/A	N/A	N/A
Beta	1900	11/24/2023	7836	1839	1900	Head	1.44	40.4	PASS	PASS	PASS	GMSK	PASS	N/A
Delta	2450	01/05/2024	7857	1843	2450	Head	1.86	40.1	PASS	PASS	PASS	OFDM	N/A	PASS
Delta	2600	01/05/2024	7857	1843	2600	Head	1.98	39.9	PASS	PASS	PASS	TDD	PASS	N/A
Beta	5250	12/27/2023	7836	1839	5250	Head	4.61	35.1	PASS	PASS	PASS	OFDM	N/A	PASS
Beta	5600	12/27/2023	7836	1839	5600	Head	4.99	34.5	PASS	PASS	PASS	OFDM	N/A	PASS
Beta	5750	12/27/2023	7836	1839	5750	Head	5.16	34.2	PASS	PASS	PASS	OFDM	N/A	PASS

NOTE: The probes have been calibrated for both CW and modulated signals. Modulations in the table above represent test configurations for which the measurement system has been validated per FCC KDB Publication 865664 D01 for scenarios when CW probe calibrations are used with other signal types.

SAR systems were additionally validated for modulated signals with a periodic duty cycle or with a high PAR (peak to average ratio) >5 dB, such as OFDM according to FCC KDB Publication 865664 D01 v01r04.

B.4. Sample TSL Compositions

TSL recipes are proprietary to SPEAG. Since the composition is approximate to the actual liquids utilized, the manufacturer data sheets are provided below.



Results

f (MHz)	Measured			Target		Diff. to Target (%)	
	ϵ'	ϵ''	σ	ϵ	σ	$\Delta\epsilon$	$\Delta\sigma$
600	44.7	25.6	0.86	42.7	0.88	4.6	-2.5
750	44.2	21.7	0.90	41.9	0.88	5.4	0.7
800	44.0	20.7	0.92	41.7	0.90	5.6	2.5
825	44.0	20.3	0.93	41.6	0.91	5.8	2.6
835	44.0	20.1	0.94	41.5	0.91	5.9	3.1
850	43.9	19.9	0.94	41.5	0.92	5.8	2.6
900	43.8	19.2	0.96	41.5	0.97	5.5	-1.0
1400	42.8	15.2	1.18	40.6	1.18	5.4	0.0
1450	42.7	15.0	1.21	40.5	1.20	5.4	0.8
1600	42.4	14.4	1.29	40.3	1.28	5.2	0.4
1625	42.4	14.4	1.30	40.3	1.30	5.3	0.1
1640	42.4	14.3	1.31	40.3	1.31	5.3	0.3
1650	42.4	14.3	1.31	40.2	1.31	5.4	-0.2
1700	42.3	14.2	1.34	40.2	1.34	5.3	-0.2
1750	42.2	14.1	1.37	40.1	1.37	5.3	-0.1
1800	42.1	14.0	1.40	40.0	1.40	5.3	0.0
1810	42.1	13.9	1.41	40.0	1.40	5.3	0.7
1825	42.1	13.9	1.42	40.0	1.40	5.3	1.4
1850	42.1	13.9	1.43	40.0	1.40	5.3	2.1
1900	42.0	13.8	1.46	40.0	1.40	5.0	4.3
1950	41.9	13.7	1.49	40.0	1.40	4.7	6.4
2000	41.8	13.7	1.52	40.0	1.40	4.5	8.6
2050	41.8	13.6	1.55	39.9	1.44	4.7	7.3
2100	41.7	13.6	1.59	39.8	1.49	4.7	6.8
2150	41.6	13.6	1.62	39.7	1.53	4.7	5.7
2200	41.6	13.5	1.66	39.6	1.58	4.9	5.2
2250	41.5	13.5	1.69	39.6	1.62	4.9	4.2
2300	41.4	13.5	1.73	39.5	1.67	4.9	3.8
2350	41.4	13.5	1.77	39.4	1.71	5.1	3.4
2400	41.3	13.6	1.81	39.3	1.76	5.1	3.1
2450	41.2	13.6	1.85	39.2	1.80	5.1	2.8
2500	41.2	13.6	1.89	39.1	1.85	5.3	1.9
2550	41.1	13.6	1.93	39.1	1.91	5.2	1.1
2600	41.0	13.6	1.97	39.0	1.96	5.1	0.3

Dielectric Permittivity ϵ'

Frequency MHz

Dielectric Conductivity σ

Frequency MHz

f (MHz)	ϵ'	ϵ''	σ	$\Delta\epsilon$	$\Delta\sigma$
3500	39.4	14.1	2.75	37.9	2.91
3700	39.1	14.3	2.94	37.7	3.12
5200	36.6	16.0	4.62	36.0	4.66
5250	36.5	16.1	4.69	35.9	4.71
5300	36.4	16.2	4.76	35.9	4.76
5500	36.2	16.4	5.03	35.6	4.96
5600	36.1	16.5	5.14	35.5	5.07
5700	35.9	16.5	5.25	35.4	5.17
5800	35.7	16.6	5.34	35.3	5.27
6000	35.1	16.5	5.52	35.1	5.48
6500	34.4	17.1	6.19	34.5	6.07
7000	33.6	17.5	6.81	33.9	6.65
7500	32.6	17.8	7.41	33.3	7.24
8000	31.7	18.0	8.01	32.7	7.84
8500	30.8	18.2	8.62	32.1	8.45
9000	30.0	18.5	9.24	31.5	9.08
9500	29.1	18.6	9.85	31.0	9.71
10000	28.2	18.7	10.41	30.4	10.36

TSL Dielectric Parameters

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Figure 1 - Head TSL Calibration Certificate Example

Measurement Certificate / Material Test

Item Name Head Tissue Simulating Liquid (HBBL4-250V3)
Product No. SL AAH 005 AD (Batch: 230809-2)
Manufacturer SPEAG

Measurement Method

TSL dielectric parameters measured using calibrated DAK probe.

Setup Validation

Validation results were within $\pm 2.5\%$ towards the target values of Methanol.

Target Parameters

Target parameters as defined in the IEEE 1528 and IEC 62209 compliance standards.

Test Condition

Ambient Environment temperature $(22 \pm 3)^\circ\text{C}$ and humidity $< 70\%$.
TSL Temperature 22°C
Test Date 10-Aug-23
Operator CL

Additional Information

TSL Density 1.042 g/cm³
TSL Heat-capacity 3.574 kJ/(kg·K)

f (MHz)	Measured			Target		Off to Target (%)	
	ϵ'	ϵ''	$\tan\delta$	ϵ'	$\tan\delta$	$\Delta\epsilon'$	$\Delta\tan\delta$
5	54.4	2887.67	0.75	55.5	0.75	-1.9	0.0
10	54.7	1344.05	0.75	55.5	0.75	-1.4	0.0
15	54.5	896.79	0.75	55.3	0.75	-1.5	0.0
20	54.3	675.18	0.75	55.1	0.75	-1.5	0.0
25	54.1	520.04	0.75	55.0	0.75	-1.6	0.0
30	53.9	440.85	0.75	55.0	0.75	-2.0	0.0
35	53.7	385.84	0.75	54.9	0.75	-2.0	0.0
40	53.5	336.02	0.75	54.8	0.75	-2.3	0.0
45	53.3	300.86	0.75	54.7	0.75	-2.5	0.0
50	53.2	271.17	0.75	54.6	0.75	-2.5	-0.1
55	53.0	246.90	0.78	54.4	0.75	-2.0	1.2
60	52.9	226.71	0.78	54.3	0.75	-2.0	1.1
65	52.7	209.64	0.78	54.2	0.75	-2.8	1.1
70	52.6	195.02	0.78	54.1	0.75	-2.8	1.0
75	52.5	182.36	0.78	54.0	0.75	-2.8	1.0
80	52.3	171.29	0.78	53.9	0.75	-2.9	0.9
85	52.2	161.53	0.78	53.8	0.75	-2.9	0.9
90	52.1	152.87	0.77	53.7	0.75	-2.9	2.1
95	52.0	145.12	0.77	53.5	0.75	-2.9	2.1
100	51.9	138.15	0.77	53.4	0.75	-2.9	2.0
105	51.8	131.86	0.77	53.3	0.76	-2.8	2.0
110	51.7	126.14	0.77	53.2	0.76	-2.8	1.9
115	51.6	120.93	0.77	53.1	0.76	-2.8	1.8
120	51.5	116.15	0.78	53.0	0.76	-2.8	3.1
125	51.3	111.77	0.78	52.9	0.76	-3.0	3.1
130	51.2	107.72	0.78	52.8	0.76	-2.9	3.0
135	51.1	103.98	0.78	52.6	0.76	-3.6	2.9
140	51.0	100.51	0.78	52.5	0.76	-3.6	2.9
145	50.9	97.29	0.78	52.4	0.76	-3.6	2.8
150	50.8	94.28	0.79	52.3	0.76	-3.6	4.1
155	50.7	91.47	0.79	52.1	0.76	-3.6	3.6
160	50.6	88.83	0.79	51.8	0.77	-2.4	3.1
165	50.5	86.36	0.79	51.6	0.77	-2.1	2.6
170	50.4	84.04	0.79	51.4	0.77	-1.8	2.1
175	50.3	81.84	0.80	51.1	0.78	-1.6	2.9
180	50.3	79.78	0.80	50.9	0.78	-1.2	2.4
185	50.2	77.83	0.80	50.7	0.78	-0.9	2.0
190	50.1	75.98	0.80	50.4	0.79	-0.7	1.5
195	50.0	74.23	0.81	50.2	0.79	-0.4	2.3
200	49.9	72.57	0.81	50.0	0.80	-0.1	1.6
205	49.8	70.99	0.81	49.7	0.80	0.1	1.3
210	49.7	69.49	0.81	49.5	0.80	0.4	0.9
215	49.6	68.06	0.81	49.3	0.81	0.7	0.4
220	49.6	66.70	0.82	49.0	0.81	1.2	1.2
225	49.5	65.39	0.82	48.8	0.81	1.4	0.8
230	49.4	64.15	0.82	48.6	0.82	1.7	0.3
235	49.3	62.96	0.82	48.3	0.82	2.0	-0.1
240	49.2	61.83	0.83	48.1	0.82	2.3	0.6
245	49.2	60.73	0.83	47.9	0.83	2.8	0.2
250	49.1	59.69	0.83	47.6	0.83	3.1	-0.3

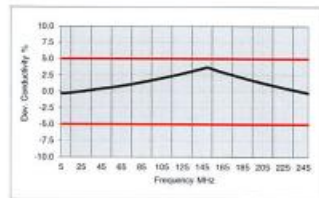
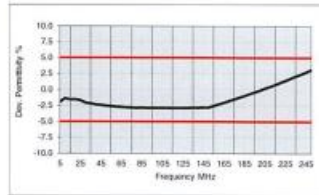


Figure 2 - Head TSL Calibration Certificate Example