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References

[1] ANSI C63.19 rev. 3.12

Goal

T-Coil probe AM1DV2 shall be characterized for compliance with standard [1] regarding frequency response and dynamic range. The relevant sections are:

C.5 Calibration of hearing aid probe coil: The linearity shall not deviate from the ideal **frequency response** characteristic by more than 0.5 dB between 100 Hz and 10 kHz, referenced to 1 kHz

C.5.1 Linearity: For fields from 0 to -50 dB A/m, the **amplitude linearity** shall be within +/- 0.5 dB.

General setup

The SPEAG T-Coil system uses an active probe with preamplifier which does not allow to access the probe coil signal separately. The probe amplifier is supplied through the signal cable from the AMMI. For these tests, the setup was in the same configuration as used in the customer labs (AM1DV2 probe, AMCC Helmholtz calibration coil, AMMI Audio Magnetic Measuring Instrument). Probe signal levels anre measured after digitization (with 24 bit and 48 kHz sampling rate) and therefore include probe coil, probe amplifiers, probe cable, AMMI supply decoupling, digitizer input stages and ADC.

The external instruments and tools used are described in the single tests.

Conclusion

Even without compensation, linearity and dynamic range of the probe system are within the limits of the standard [1].

Measurements

Amplitude linearity measurement 1

In a first step, the linearity was verified at 1 kHz with an Agilent 33120A sine generator. Its amplitude setting allowed setting of magnetic fields between approx. +15 and -25 dB A/m. The digtized probe output was read in a software third-octave analyzer from the digitizer at the fixed frequency.
The level setting (resolution 0.01 dB) of the generator was changed in 10.00 dB steps. In the amplitude range between +15 dB A/m to –25 dB A/m, the reading changed also in 10.00 dB steps.

Result: The linearity deviation in a dynamic range of 40 dB was < 0.01 dB.

Amplitude linearity measurement 2

Due to the limitation of the generator attenuator, a further setup was used for the linearity range over a wider range.

To increase the measurable dynamic range, a different generator with a high range step attenuator (Rohde&Schwarz SML 02 (9 kHz and higher) was used at 10 kHz for these measurements. The higher probe sensitivity and the lower noise level at 9 kHz allowed a measurement over a dynamic range of >85 dB. To reduce errors from the RF step attenuator, the AMCC current amplitude was measured with a Rohde&Schwarz UPL audio analyzer. The digitized probe output, read from a software third-octave analyzer on the PC was compared to the UPL audio analyzer reading at 10 kHz. The results are shown in the following table, the levels regarding magnetic field are not calibrated.

Generator dBm	Coil (UPL) dBV	Probe reading dB A/m	Diff, normalized dB	Noise suppression dB	Diff, expected from noise dB	Difference, effective dB
9.29	-19.924	**0.00**	0.00	85.4	0.00	**-0.00**
-0.71	-30	**-10.07**	0.01	75.33	0.00	**0.01**
-10.71	-40.07	**-20.13**	0.02	65.27	0.00	**0.02**
-20.71	-49.95	**-30.01**	0.02	55.39	0.00	**0.02**
-30.71	-60.21	**-40.27**	0.02	45.13	0.00	**0.02**
-40.71	-69.6	**-49.65**	0.03	35.75	0.00	**0.02**
-50.71	-79.45	**-59.50**	0.03	25.9	0.01	**0.01**
-60.71	-89.42	**-69.40**	0.10	16	0.11	**-0.01**
-70.71	-99.31	**-78.60**	0.79	6.8	1.02	**-0.23**
off (noise level)		-85.40				

In a dynamic range of 50 dB, the deviation of the probe reading from the reference instrument was deviating <0.03 dB absolute, and <0.02 dB from the expected reading considering the influence of the probe system noise level.
Over the measured dynamic range of 78.6 dB (i.e. down to 6.8 dB over the noise level), the deviation from the expected reading was < 0.23 dB.

Result: The probe system fulfils the requirements regarding linearity of the dynamic range.

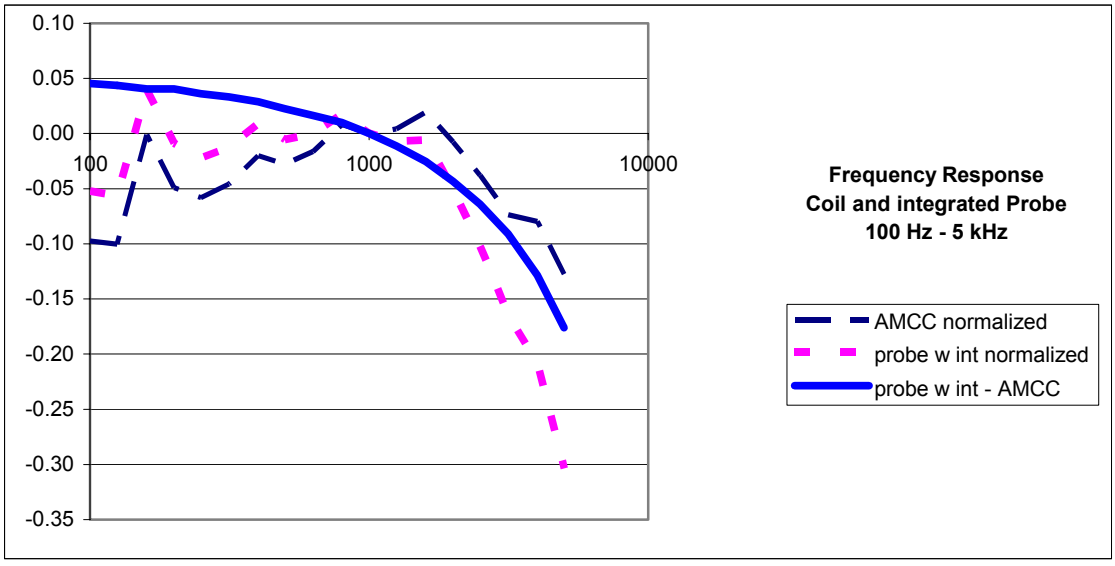
Frequency response measurement 1

This evaluation bases on the data available to the DASY4 operator. It is limited to 5 kHz.

During the probe system calibration process, a multisine signal is applied to the AMCC. Its current (equivalent to the magnetic field) is monitored and digitized with one channel, the probe signal with the other channel. Both digitized inputs are evaluated with the same third-octave filter bank from 100 to 5’000 Hz. This process is used to calibrate the probe and its response before a measurement
The exported numerical data of such an example have been compared after applying an ideal integrator to the coil signal to extract the probe system response (deviation from the ideal curve).

(Note: Mesaurements after this calibration are compensated with this deviation, i.e. the frequency response is eliminated for subsequent measurements. The response visible in this evaluation is therefore an intermediate result and not present (calibrated out) during system usage!)

frequency Hz	probe voltage dB V	AMCC voltage dB V	theoretical integrator dB	probe with integrator dB	AMCC normalized dB	probe w int normalized dB	probe w int - AMCC dB
100	-51.86	-28.22	-20.00	-31.86	-0.10	-0.05	0.05
125	-49.92	-28.23	-18.06	-31.86	-0.10	-0.06	0.04
160	-47.68	-28.13	-15.92	-31.76	0.00	0.04	0.04
200	-45.79	-28.18	-13.98	-31.81	-0.05	-0.01	0.04
250	-43.87	-28.19	-12.04	-31.83	-0.06	-0.02	0.04
315	-41.85	-28.17	-10.03	-31.82	-0.05	-0.01	0.03
400	-39.75	-28.15	-7.96	-31.80	-0.02	0.01	0.03
500	-37.83	-28.16	-6.02	-31.81	-0.03	-0.01	0.02
630	-35.82	-28.14	-4.01	-31.80	-0.02	0.00	0.02
800	-33.72	-28.12	-1.94	-31.79	0.01	0.02	0.01
1000	-31.80	-28.13	0.00	-31.80	0.00	0.00	0.00
1250	-29.87	-28.12	1.94	-31.81	0.00	-0.01	-0.01
1600	-27.73	-28.11	4.08	-31.81	0.02	-0.01	-0.03
2000	-25.83	-28.13	6.02	-31.86	-0.01	-0.05	-0.04
2500	-23.95	-28.17	7.96	-31.91	-0.04	-0.10	-0.06
3150	-22.00	-28.20	9.97	-31.97	-0.07	-0.16	-0.09
4000	-19.97	-28.21	12.04	-32.01	-0.08	-0.21	-0.13
5000	-18.13	-28.25	13.98	-32.11	-0.13	-0.30	-0.18



Remarks: Normalizations are to 1 kHz. An AMCC voltage of -20 dB V is equivalent to 1 A/m. Calibration level is -8.1 dB A/m = 0.39 A/m.

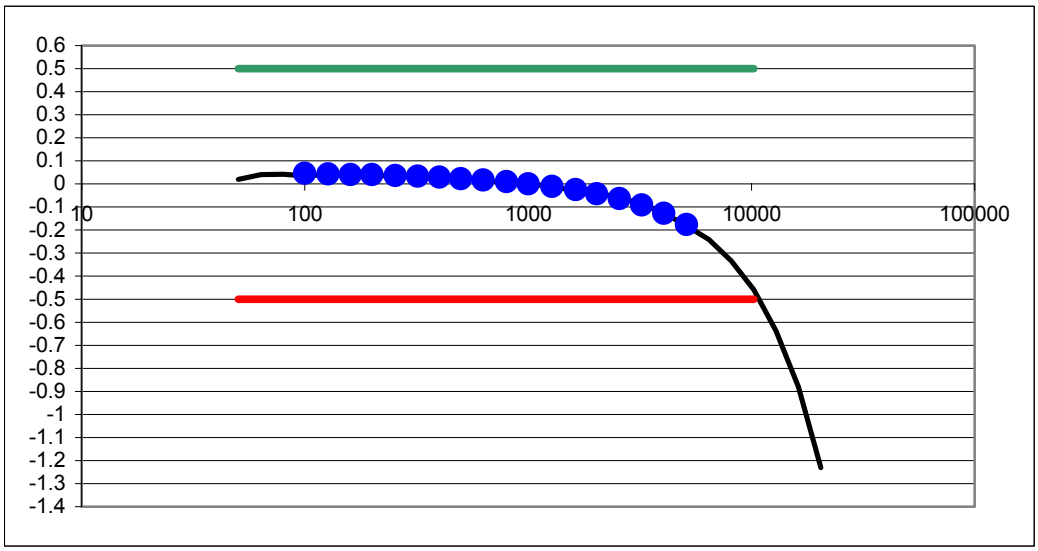
Result: The frequenc response of the complete probe system is within 0.18 dB up to 5 kHz.

Frequency response measurement 2

Due to the limitation of the display to 5 kHz, measurements were made with separate instruments similar as above in a larger frequency range. Single frequency measurements were made, setting Agilent generator 33120 to the desired frequency and monitoring the AMCC coil current (equivalent to the field) with the Rohde&Schwarz UPL audio analyzer (third-octave bands). The digitized probe output was read

from a software third-octave analyzer on the PC, applying the compensation of an ideal integrator. The results for the frequency range 50 Hz to 20.5 kHz are shown in the following table, the levels regarding magnetic field are not calibrated. For comparison measurements 1 are shown in the same graphical representation using dots.

frequency Hz	Coil current dB	Probe with integrator dB	Probe deviation dB	Result from method 1 dB
50.4	-13.02	-0.06	0.02	
63.5	-12.88	0.1	0.04	
80	-12.64	0.342	0.042	
100	-12.9	0.075	0.035	0.05
127	-12.83	0.151	0.041	0.04
160	-12.96	0.02	0.04	0.04
200	-12.89	0.09	0.04	0.04
254	-12.81	0.16	0.03	0.04
320	-12.78	0.192	0.032	0.03
400	-12.88	0.085	0.025	0.03
500	-12.88	0.083	0.023	0.02
630	-12.93	0.025	0.015	0.02
800	-12.81	0.135	0.005	0.01
1000	-12.94	0	0	0.00
1280	-12.83	0.099	-0.011	-0.01
1630	-12.78	0.129	-0.031	-0.03
2030	-12.88	0.021	-0.039	-0.04
2560	-12.88	0	-0.06	-0.06
3230	-12.92	-0.067	-0.087	-0.09
4060	-12.98	-0.167	-0.127	-0.13
5120	-13.01	-0.252	-0.182	-0.18
6450	-13.21	-0.512	-0.242	
8130	-13.42	-0.815	-0.335	
10240	-13.76	-1.278	-0.458	
12900	-14.24	-1.937	-0.637	
16250	-14.93	-2.87	-0.88	
20480	-15.87	-4.16	-1.23	



Result: The raw frequency response of the uncompensated probe system in the range 100 Hz to 10 kHz is < 0.5 dB. The correlation with the measurements above is excellent.

