

## SETTING OF THE T-COIL AUDIO GAIN LEVEL

### General

This technical note shows the steps for finding the correct settings and gain levels in the T-Coil jobs when used within DASY software. In addition, numerical examples are given as well. Please note that some values depend on the used instruments (AMMI, CMU200) and thus need modification / recalculation for each setup. This document comes with an accompanying Excel sheet which can be used to calculate the level [5]. For instructions related to VoLTE and VoWLAN please refer to [6] and [7]

For HAC T-coil tests, the speech level shall be set to a level of -16 or -18 dBm0 according to [1] Section 7.4.2.1 Reference input level, table 7.1, [2], [3]. For protocols not listed in [1] a level of -20 dBm0 should be used according to [4].

### References:

- [1] ANSI C63.19-2011
- [2] C63.19-2011\_interpretation\_T-coil\_audio\_levels\_for\_LTE\_July\_2012.pdf
- [3] CTIA Test Plan for Hearing Aid Compatibility, V3.1, February 2017
- [4] FCC 285076 D02 T-Coil Testing v03, September 12, 2017
- [5] TN-LK-180405-C-T-Coil\_Levels\_Calculation.xls
- [6] TN-BK-06032018-C-VoLTE\_T-coil\_w\_CMW500.pdf
- [7] TN-BK-10032018-C-VoWLAN\_T-coil\_w\_CMW500.pdf

### Overview

This document is divided in following sections:

- Description of the hardware setup
- T-Coil calibration job for AMMI in the setup with AMCC and the AM1D probe
- T-Coil reference jobs for all signals to be used, with the AMCC connected to the AMMI
- The gain level determination to obtain a specific level in dBm0 with R&S CMU200
- The gain level determination to obtain a specific level in dBm0 with other calibrated simulators
- Thee gain level calculation per signal type and dBm0 level needed
- Setting of gain levels, verification of plausibility and settings and voice signal at the speaker

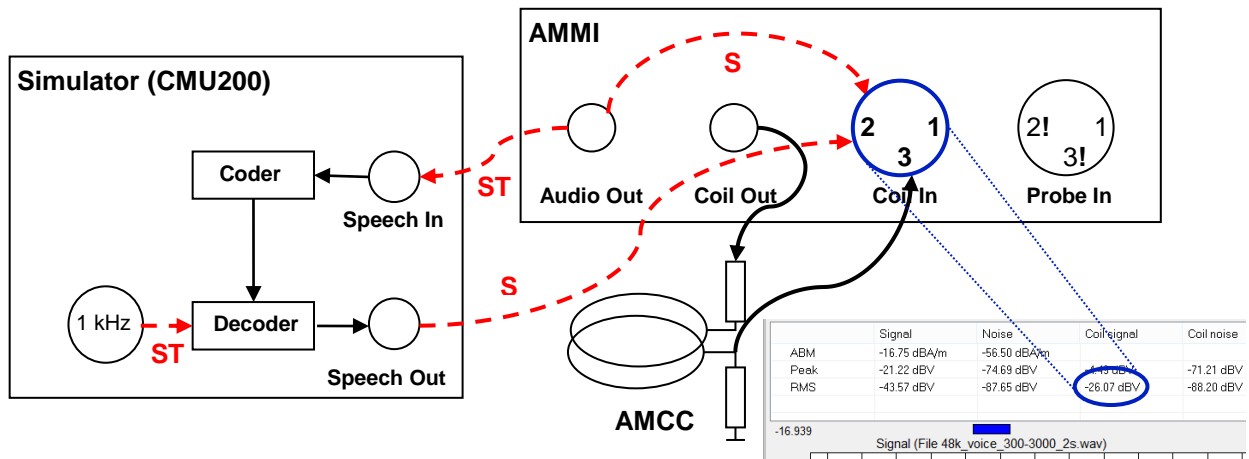
### Hardware Setup

Hardware setup (AMMI, AMCC, AM1DVx probe) shall be as described in DASY manual chapter "HAC T-Coil".

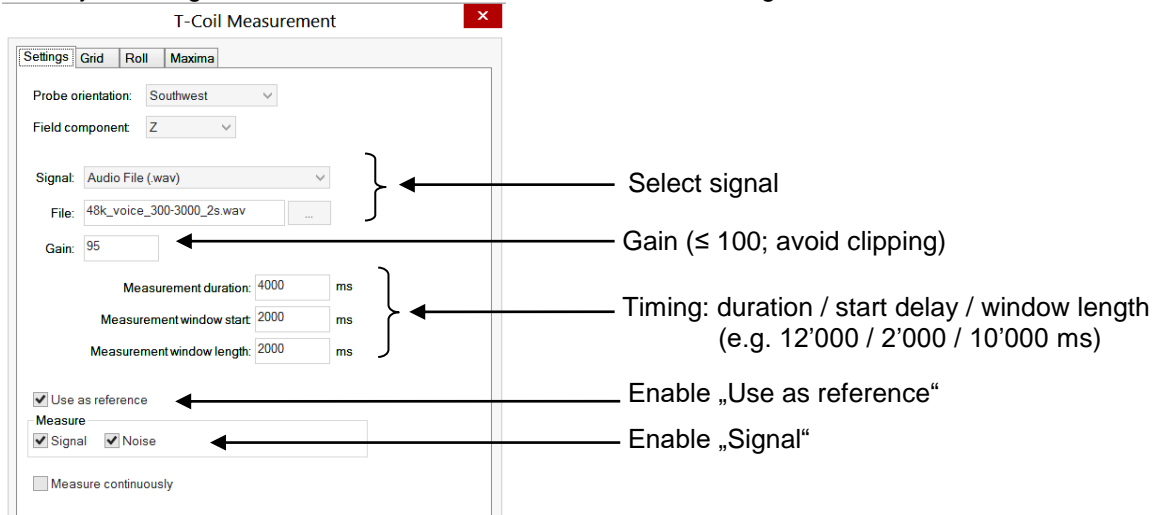
The base station simulator must be equipped with the required audio options to establish a voice call in the desired operating mode. (RF settings are not part of this document. Please consult the base station simulator manual for further details on this requirement).

Cables to connect the analog speech signal from AMMI Audio Out (BNC) to the simulator input must be available. For CMU200, the input connector is a D-sub type with inputs and outputs for codecs LH1 and LH2; for most other simulators e.g. CMW500, standard BNC connectors are used. Connection to AMMI 'Coil In' can be done via a BNC-XLR adapter if required.

Below diagram is showing setup of AMMI for 'Coil In' signal RMS readings:



T-Coil job settings within DASY software for 'Coil In' RMS readings shall be as follows:



### T-Coil calibration job for AMMI in the setup with AMCC and the AM1DVx probe

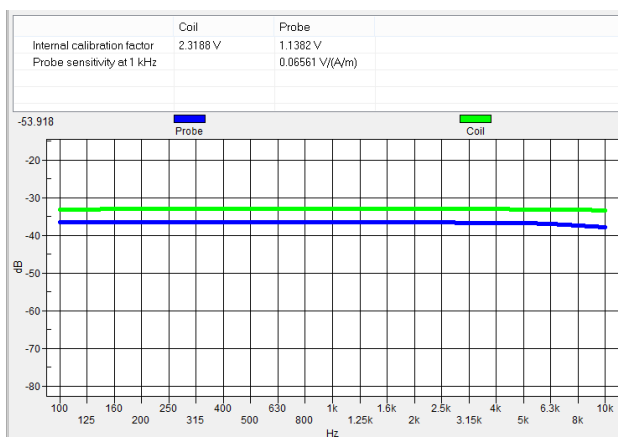
Run a T-Coil calibration job:

Signal: Calibration

Timing: 7'000 / 2'000 / 5'000 ms

Grid anchor: "User point – AMCC Center"

Verify the plausibility of the results before continuing. Below figure shows typical calibration job result for AM1DV2 probe. After this job, the AMMI "Coil In" is calibrated to read the RMS voltage.



Internal calibration factor: Coil: approx. 2.3, Probe: approx. 1.15

Coil spectrum (green line): nearly straight line, at –33 dB for gain 100, decay < 0.5 dB @ 10 kHz

Probe spectrum (blue line): parallel to coil line, decay 0.9 dB larger

Probe sensitivity: close to probe calibration value

## T-Coil reference job for all signals to be used, with the AMCC connected to the AMMI

With the AMCC connected to AMMI “Coil In”, run a set of T-Coil Reference jobs with all signals needed, including the internal “1 kHz sine” signal. These measurements with the settings “use as reference” are needed in the initial T-Coil measurements to determine the frequency spectrum of the signal and later compensate it with the BWC (bandwidth compensation factor), Select a high gain (90 – 100) and make sure there is no clipping in the measurement.

Since there is no codec involved when measuring the internal 1 kHz reference signal in the CMU200 (Decoder Cal), the timing is selected without any additional delay.

Use a duration of the signal period or multiple periods with at least 10'000 ms window length.

Due to internal switching in the AMMI for “use as reference” measurements, a delay of ‘n\*signal\_duration’ or at least 2'000 ms shall be set for all other signals.

Grid anchor: “AMCC Center”

Enable “Use as reference”

Use the following signals:

- Signal: 1 kHz Sine, gain: 100, Timing: 12'000 / 2'000 / 10'000 ms
- Signal: 48k\_voice\_1kHz\_1s, gain: 100, Timing: 12'000 / 2'000 / 10'000 ms
- Signal: 48k\_voice\_300-3000\_2s, gain: 100, Timing: 12'000 / 2'000 / 10'000 ms
- all further signals needed during T-Coil testing, gain: ≤100 (no clipping), Timing: <signal\_duration> + <start delay> / <start delay> / <signal\_duration> (example for “Normal” signal with 51 s duration: 53'000 / 2'000 / 51'000 ms).

After job is completed, enter the used Gain and ‘Coil signal’ RMS level for each signal into the Excel file [5] at ① and ②.

1kHz Sine is used to calculate the basic gain settings. Therefore, the differences of the other signals towards 1kHz sine is calculated. The calculation steps are explained in below figure (see also accompanying Excel file [5]).

Signal type	Path / Connection	Gain (linear) ①	Gain dB	Coil_In reading dBV (RMS) ②	Difference to 1 kHz sine dB	Gain factor Lin
1 kHz sine	Use as reference	100	40.00	-6.73	0.00	-
1.025 kHz sine	Use as reference	100	40.00	-6.73	0.00	1.00
voice 1 kHz	Use as reference	100	40.00	-19.46	-12.73	4.33
voice 300-3kHz	Use as reference	100	40.00	-25.31	-18.58	8.49
normal (example)	Use as reference	100	40.00	-29.17	-22.44	13.24
	Use as reference		-		-	-
	Use as reference		-		-	-
	Use as reference		-		-	-

$20 \cdot \log(\text{gain\_linear})$  ③
 $10^{-(\text{gain\_dB}/20)}$  ⑭

- ① Used gain level for the signal (see T-Coil job settings)
- ② RMS Reading from ‘Coil signal’ for the specific signal measured (see hardware setup)
- ③ Gain in dB =  $20 \cdot \log(\text{Gain\_linear})$
- ④ Gain difference (dB) = ‘②\_signal’ – ‘②\_1kHz\_Sine’ – ‘③\_signal’ + ‘③\_1kHz\_Sine’
- ⑭ Gain factor (lin) =  $10^{-(\text{gain\_dB}/20)}$ .

Column ⑭ contains the linear gain factors needed to get the same RMS average amplitude as for a 1 kHz sine signal. It compensates for the difference in dB in column ④. It will later be used to calculate the signal specific gain settings.

## The gain level determination to obtain a specific level in dBm0 with R&S CMU200

Base station simulators with an analog speech input have an internal level of 3.14 dBm0 (alpha type codecs) for a full-scale signal.

For uncalibrated simulators (e.g. R&S CMU200) the reference level in dBm0 depend on the instrument, the signaling unit used and on the AMMI.

For simulators with calibrated inputs (e.g. R&S CMW500, Agilent, Anritsu) where the input sensitivity dBm0 per input voltage) is known or can be set, use the following section of this document.

**START:** Connect the CMU200 (Speech OUT) with AMMI (Coil IN) as in hardware setup diagram.

Connect AMMI "Audio Out" to CMU200 "Speech In" for the selected codec LH1 or LH2. (SPEAG offers two sets of cables which can be used for the connection on the Sub-D "Speech" connector):

Pin	Signal	Usage
2	LH1HAND SETIN	(GSM/WCDMA signals from AMMI to CMU200)
3	LH1HAND SETOUT	(GSM/WCDMA signals from CMU200)
5	LH2HAND SETIN	(CDMA signals from AMMI to CMU200)
6	LH2HAND SETOUT	(CDMA signals from CMU200)

Connect "Speech Out" (for the selected signaling unit) via BNC-XLR adapter to AMMI "Coil In". With an active call set up (call established, detailed settings not relevant), perform the following measurements:

**STEP A:** Select "Bit Stream" "**Decoder Calibration**" on the CMU200; the internal full-scale 1 kHz signal (see hardware setup diagram) will be available at the CMU200 "Speech Out" and can be measured using AMMI "Coil In".

Use a T-Coil job with the settings

Signal: "Off",

Gain: 10 (default value),

Timing: 10'300 / 300 / 10'000 ms,

"use as reference" disabled.

Read AMCC 'Coil In' signal (dBV\_RMS) according to hardware setup diagram. The signal is a 1 kHz sine from the CMU200 internal source and corresponds to 3.14 dBm0. Example: -2.44 dBV\_RMS

Enter the value into the Excel sheet at ⑤

**STEP B:** Select 'Bit Stream' - '**Codec Calibration**' on the CMU200; the AMMI signal from 'Speech In' will be looped through to the 'Speech Out' and can be compared to the reference reading.

Use a T-Coil job with the settings

Signal: "1 kHz Sine",

Gain: 10 (default value),

Timing: 10'300 / 300 / 10'000 ms, assuming a 300 ms delay through coder and decoder, "use as

reference" OFF.

Enter the gain level used for '1KHz Sine' into the Excel sheet at ⑥

Read the AMCC 'Coil In' signal (dBV\_RMS) according to hardware setup diagram and enter the value into the Excel sheet at ⑦

**STEP C:** Calculate the required gain settings for a “1 kHz Sine” according to:

The gain level determination for 1 kHz sine to obtain a specific level in dBm0 with R&S CMU200			
<b>STEP A:</b>			
Select "Bit Stream" "Decoder Calibration" on the CMU200.			
Measure the internal full-scale 1 kHz signal (see hardware setup diagram) using AMMI "Coil In".			
'Coil_In' signal reading (dBV_RMS) :	⑤	-2.45	[dBV]
The measured level in ⑤ is equal to the reference level of:		3.14	[dBm0]
<b>STEP B:</b>			
Select 'Bit Stream' - 'Codec Calibration' on the CMU200.			
Measure the AMMI 1kHz sine looped through the CMU200 using AMMI 'Coil_In' (see T-coil job setting)			
Gain level used (linear):	⑥	10	=> ③ 20.00 [dB]
'Coil_In' signal reading (dBV_RMS) :	⑦	-19.77	[dBV]
The 1 kHz sine level measured in ⑦, using a gain of ⑥ corresponds to a level of ⑧ in dBm0.			
	⑧	-14.18	[dBm0]
<b>STEP C:</b>			
Calculate the required gain setting for a '1 kHz Sine' using data from 6B.			
Required level:	⑨	-16.00	[dBm0]
To obtain an audio level of -16 dBm0 requires a gain of:	⑩	18.18	[dB] => ⑪ 8.11 (linear)
For other required audio levels the (linear) gain level set in DASY should be:			
1 kHz sine (linear) gain level needed for:	-16.00	[dBm0]	=> ⑩ => ⑪ => 8.11
1 kHz sine (linear) gain level needed for:	-18.00	[dBm0]	=> ⑩ => ⑪ => 6.44
1 kHz sine (linear) gain level needed for:	-19.00	[dBm0]	=> ⑩ => ⑪ => 5.74
1 kHz sine (linear) gain level needed for:	-20.00	[dBm0]	=> ⑩ => ⑪ => 5.12
<b>STEP D:</b>			
To verify the calculation in 6C, repeat the T-coil job specified in 6B. Or create a copy of the job.			
Set the T-coil job gain to the level found in ⑪.			
The AMCC 'Coil In' signal (dBV_RMS) reading should be equal or very close to:		⑫	-21.59 [dBV]
a 1 kHz sine audio level of -16 dBm0 gives a 'Coil_In' signal reading of:		⑫	-21.59 [dBV]
a 1 kHz sine audio level of -18 dBm0 gives a 'Coil_In' signal reading of:		⑫	-23.59 [dBV]
a 1 kHz sine audio level of -19 dBm0 gives a 'Coil_In' signal reading of:		⑫	-24.59 [dBV]
a 1 kHz sine audio level of -20 dBm0 gives a 'Coil_In' signal reading of:		⑫	-25.59 [dBV]

- ⑤ CMU200 internal 1kHz sine reference equal to 3.14 dBm0 measured in dBV.
- ⑥ Gain level used in DASY job.
- ⑦ AMMI 1 kHz sine routed through CMU200 measured in dBV.
- ⑧ Level of the 1 kHz Sine with gain ⑦ in dBm0 = ⑦ - ⑤ + 3.14. Example: -14.18 dBm0
- ⑨ Desired audio level in dBm0.
- ⑩ Gain [dB] needed to obtain audio level of -16 dBm0 = ⑨ + ⑦ - ⑧
- ⑪ Gain converted to linear gain factor =  $10^{(⑩/20)}$ .

**STEP D:** Verify above calculation by measurement.

The calculations performed in STEP C can be verified by measurements, repeat the T-coil job specified in STEP B or create a copy of the job.

Set the T-coil job gain to the level found in ⑪ (see T-coil job settings for 'Coil In' RMS readings)  
The measured AMCC 'Coil In' signal (dBV\_RMS) should be equal or very close to ⑫

AMMI 'Coil\_In' reading should be equal or close to ⑫ = (⑨ + ⑦ - ⑧)

## Determine the gain level to obtain a specific level in dBm0 with other calibrated simulators

For simulators with calibrated inputs (e.g. R&S CMW500, Agilent, Anritsu), the analog input voltage has to be determined.

**STEP E:** Read the simulator manual or application note and determine the relation between the analog input voltage and the internal level in dBm0.

For CMW500, the standard setting is 1.0000 V full scale for 3.14 dBm0. The voltage can be changed by the user. Specify the full-scale setting (in this case for peak 1 kHz Sine, not peak-peak), and enter the value in the Excel sheet at (15).

- (15) Defined full scale input setting.
- (16) Full scale input level converted to dBV\_RMS =  $20 \cdot \log((15)/\sqrt{2})$

### STEP F: Determining the reference level in dBv.

Connect AMMI "Audio Out" according to hardware setup diagram via BNC-XLR adapter to AMMI Coil In.

Use a T-Coil job with the settings

Signal: "1 kHz Sine",  
Gain: 10, Timing: 10'000 / 0 / 10'000 ms (no delay from Codec),  
"use as reference" disabled.

Enter the used gain level in the Excel sheet at (17)

Enter the AMMI 'Coil\_In' signal reading at (18)

After the calibration procedure has been performed in DASY The AMMI 'Coil\_In' can be used as a voltmeter for dBV\_RMS (see hardware setup diagram)

However, due to different impedance on 'Audio\_out' and 'Coil\_In' a correction of -0.15 dB needs to be applied to (18).

- (17) Linear gain level used for "1 kHz Sine" reference (see T-coil job settings)
- (3) Gain in dB =  $20 \cdot \log(\text{Gain\_linear})$
- (18) RMS Reading from Coil for the "1 kHz Sine" (hardware setup diagram)
- (19) 'Coil\_In' signal corrected for impedance mismatch.  $(19) = (18) - 0.15$
- (20) Resulting reference audio level for 1 kHz sine.

The gain level determination to obtain a specific level in dBm0 with CMW500.				
<b>STEP E:</b>				
Define CMW500 analog input voltage				
Speech_In Sensitivity:	(15)	1.718	V_Fullscale =	3.14 [dBm0] pr. definition
Sensitivity converted to dBV_RMS	(16)	1.69	dBV_RMS	
<b>STEP F:</b>				
Connect AMMI "Audio Out" according to hardware setup diagram (STEP F) via BNC-XLR adapter to AMMI Coil In.				
Run a T-Coil job with settings as described in the technical note.				
Measure AMMI 1 kHz sine in dBV				
AMMI 1kHz sine, used gain level:	(17)	100	=>	(3) 40.00 [dB]
'Coil_In' signal reading (dBV_RMS) :	(18)	3.32	[dBV]	
Impedance corrected "Coil_In" signal reading :	(19)	3.17	[dBV]	
Resulting audio level of 1kHz sine with a gain of (17)	(20)	4.62	[dBm0]	

**STEP G:** Calculate required gain settings for other audio levels

Calculation scheme to determine gain settings for 1 kHz Sine with CMW500 is as follows:

<b>STEP G:</b>				
Determine gain needed to obtain desired audio level for 1 kHz sine.				
Calculate the required gain setting for a '1 kHz Sine' using data from STEP F.				
Required level:	⑨	-16.00	[dBm0]	
To obtain an audio level of -16 dBm0 requires a gain of:	⑩	19.38	[dB]	=> ⑪ 9.31 (linear)
For other required audio levels the (linear) gain level set in DASY should be:				
1 kHz sine (linear) gain level needed for:		-16.00	[dBm0]	=> ⑩ => ⑪ => 9.31
1 kHz sine (linear) gain level needed for:		-18.00	[dBm0]	=> ⑩ => ⑪ => 7.40
1 kHz sine (linear) gain level needed for:		-19.00	[dBm0]	=> ⑩ => ⑪ => 6.59
1 kHz sine (linear) gain level needed for:		-20.00	[dBm0]	=> ⑩ => ⑪ => 5.88

Please note that in this example with a sensitivity setting of 1.7180 V\_FullScale for the CMW500, the same gain setting happens to result as in the example for the CMU200 given. In reality, the values vary with the specific AMMI and simulator used!

The conversion in STEP G is equivalent to one in STEP C:

- ⑨ Desired audio level in dBm0.
- ⑩ Gain [dB] needed to obtain audio level of -16 dBm0 = ⑨ + ③ - ⑳
- ⑪ Gain converted to linear gain factor =  $10^{(⑩/20)}$ .

**STEP H:** Verify above calculation by measurement.

The calculations performed in STEP G can be verified by measurements; repeat the T-coil job specified in STEP F or create a copy of the job. Set the T-coil job gain to the level found in STEP G ⑪ (see.).

The measured AMCC 'Coil In' signal (dBV\_RMS) should be equal or very close to 7D ⑫

AMMI 'Coil\_In' reading should be equal or close to ⑫ = (⑨ + ⑱ - ⑳)

### The gain level calculation per signal type and dBm0 level

Knowing the required gain levels from above steps a "1 kHz Sine" signal, the gain levels for other signals can be calculated from the conversions as per T-Coil Reference Job according to the scheme as shown below.

Logarithmic scaling is done by compensating the gain (dB) = gain\_1kHz - ④.

Linear scaling is done as ⑭ gain\_signal (lin) = gain\_1kHz \* gain\_factor = 10^(gain\_signal\_dB/20).

The gain level calculation setting for other signals and target levels				
Knowing the required gain levels from STEP A to H for a "1 kHz Sine" signal, the gain levels for other signals can be calculated				
Use reference levels defined in section:	-Select-	Select a section		
Reference audio level	⑨ -	[dBm0]		
Corresponding 'reference' gain levels	⑩ -	[dB] =>	⑪ -	(linear)
Reference levels as found in: -Select-C				
1 kHz sine reference level needed for:	-	[dBm0]	=>	-
1 kHz sine reference level needed for:	-	[dBm0]	=>	-
1 kHz sine reference level needed for:	-	[dBm0]	=>	-
1 kHz sine reference level needed for:	-	[dBm0]	=>	-
Gain levels needed for signals listed in T-Coil reference job.				
Enter desired audio level:	-16	[dBm0]		
Signal type	Difference to 1 kHz sine [dB]	Audio level [dBm0]	Gain [dB]	Gain (linear)
	④			
1 kHz sine	-	-16.00	-	-
1.025 kHz sine	-	-16.00	-	-
voice 1 kHz	-	-16.00	-	-
voice 300-3kHz	-	-16.00	-	-
normal (example)	-	-16.00	-	-
-	-	-16.00	-	-
-	-	-16.00	-	-
-	-	-16.00	-	-

Please note that for signals with a high Peak-to-Average ratio, gains of >100 might result from the calculation. These cannot be set in the T-Coil job. Measurements must then be taken at a lower level and scaled to the target level.



## Setting of gain levels, verification of plausibility and settings and voice signal at the speaker

The gain levels calculated above have to be applied to all T-Coil measurement jobs in which the signal is used with the same AMMI and simulator.

The timing settings may need modification due to the internal delay of the codec, especially if short signals (e.g. voice\_1kHz\_1s or voice\_300-3000\_2s) are used. Assuming a codec delay of 190 ms, the settings for the voice\_1kHz\_1s would be 1'190 / 190 / 1'000 ms). For scans needed to find the best points, the settings are less important than for the final result at the selected location. Settings with longer measurement time should be chosen to reduce this sensitivity (e.g. like above: 10'190 / 190 / 10'000 ms).

Below table summarized the list of predefined signals. The table can be used to verify the resulting gain factors. The integration time of the last 3 voice signals should be an integer multiple of the signal duration.

Signal [file name]	Duration [s]	Peak-to-RMS [dB]	RMS [dB]	Required gain factor *)	Gain setting
1kHz sine	---	3.0	0.0	1.00	
48k_1.025kHz_10s.wav	10	3.0	0.0	1.00	
48k_1kHz_3.15kHz_10s.wav	10	6.0	-3.0	1.42	
48k_315Hz_1kHz_10s.wav	10	6.0	-2.9	1.40	
48k_csek_8k_441_white_10s.wav	10	13.8	-10.5	3.34	
48k_multisine_50-5000_10s.wav	10	11.1	-7.9	2.49	
48k_multisine_50-10000_10s.wav	10	10.8	-7.7	2.42	
48k_voice_1kHz_1s.wav	1	16.2	-12.7	4.33	
48k_voice_300-3000_2s.wav	2	21.6	-18.6	8.48	
48k_normal (example)	51	25.4	-22.42	13.21	

(\*) The gain for the specific signal shall typically be multiplied by this factor to achieve approx. the same level as for the 1kHz sine signal.

Insert the gain applicable for your setup in the last column of the table. Verify the gain by taking a measurement with the desired signal, gain and timing combination and fine adjust if necessary.

Audio should be audible at the speaker of the device under test with the volume set to maximum. Make sure the correct setting is chosen at the simulator (e.g. "Handset Low").