26th European Conference on Acoustic Emission
EWGAE 2004

Achievements and Limits of an Automated AE-Channel-Verification Process

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Equipment Verification, why, when, who?

EN13477-2 NDT - AE - Equipment Characterisation
Part 2: Verification of operating characteristics

Why:

- To ensure the equipment complies with the specifications

When:

- After purchase of equipment,
- After modification of equipment,
- After use under extraordinary conditions
- Routinely, (to be decided by test agency).

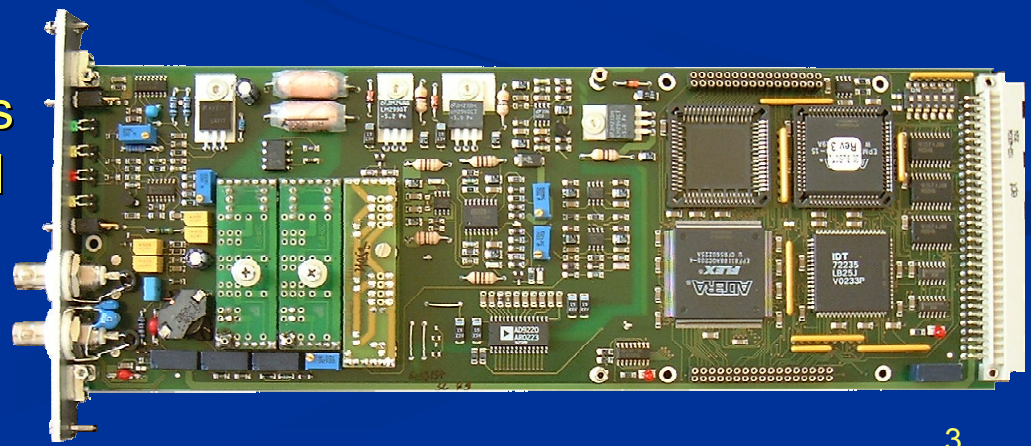
Who shall perform the verification:

- The equipment operator (verification is not a calibration)
- **Problem:** Rather disliked job, needs high concentration and good understanding of details of the equipment.

This Presentation concentrates on ASIPP Verification

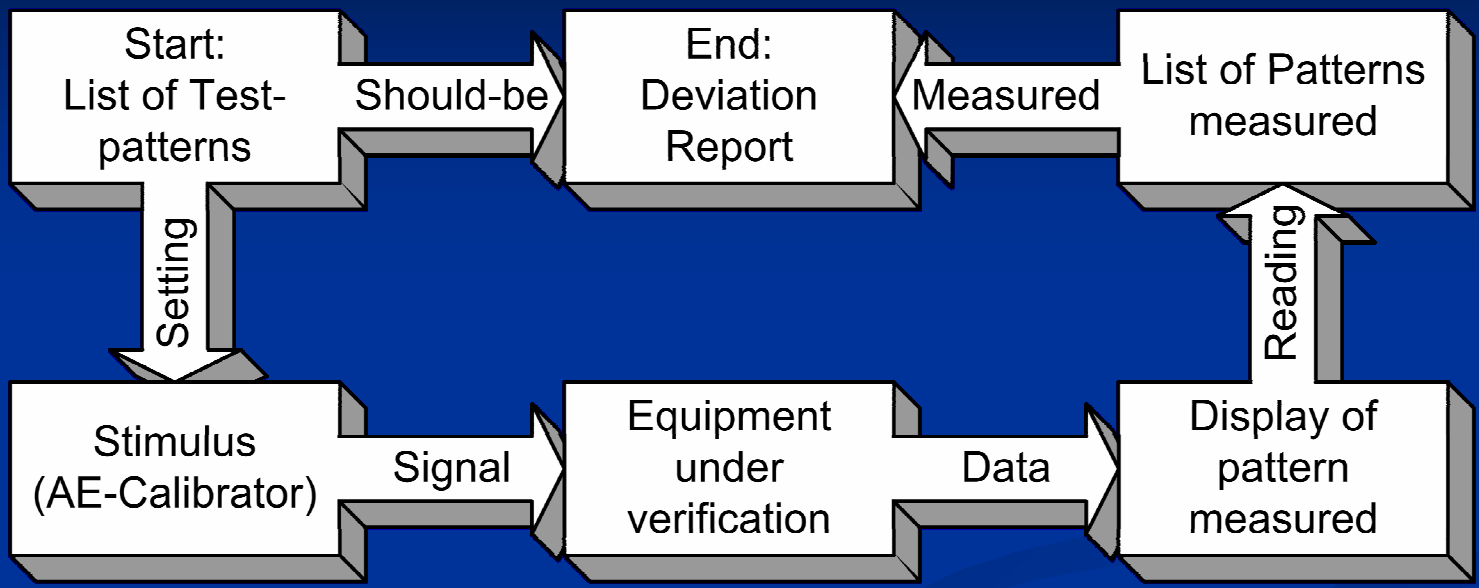
EN13477-2 treats all components of an AE multi-channel equipment:

- AE-sensors, preamplifiers, cables.
- Conditioning and measurement system
  - **ASIPP** (Vallen Term for **A**coustic **Si**gnal **P**re-**p**rozessor)
  - External Parameter Inputs
- This presentation concentrates on the verification of the signal processor, the **ASIPP**.



Overview, Achievements

AE-Channel Verification – General View



The verification procedure defines a list of test patterns (simulated AE).
The operator performs, pattern by pattern:

- Set the AE calibrator ready for the next test pattern, simulate AE signals
- Read the measurements for each pattern
- Report the deviations between measured and “should be” values
- Check if the deviations meet the acceptance criteria

Manual versus automated AE-Channel Verification

Manual:

- 12 Test patterns,12 verifications required by EN13477-2
- Indicates general faults
- Needs 4-12 hours for 32 channels (procedure dependent)
- High demands on operator concentration and reliability
- Needs AE-calibrator plus a function generator for the frequency response check
- Doesn't replace AE-channel calibration

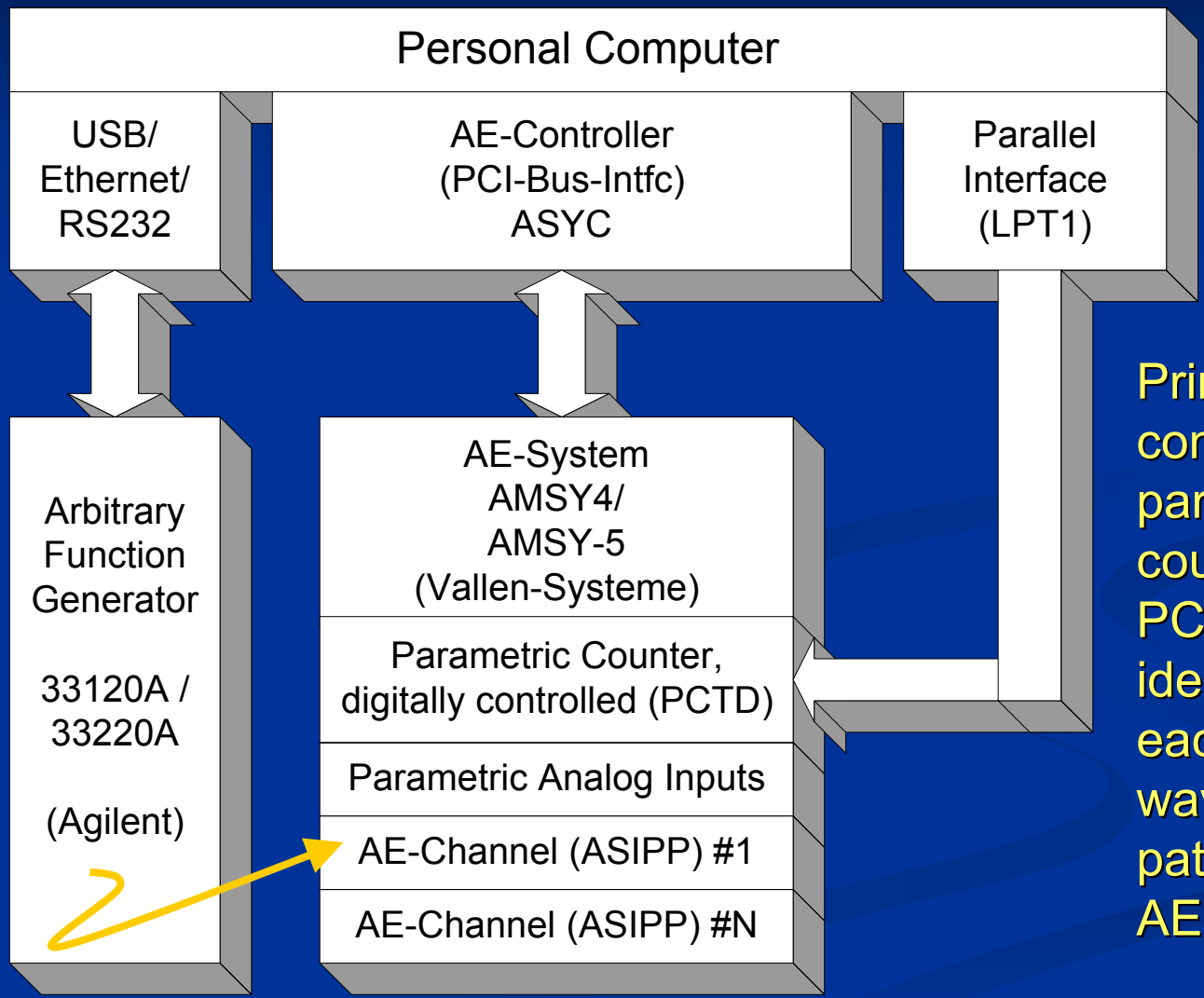
Automated:

- 112 Test patterns, 220 verifications, sufficient for a calibration run
- Precise accuracy check over a high resolution for each parameter
- Less than 1 hour for 32 channels
- Low demands on operator qualification - almost foolproof
- Needs only one device: An Arbitrary Function Generator (AFG) (waveform programmable)
- Provides clear and detailed report in MS-Word format
- **With a calibrated AFG the automated verification procedure delivers traceable results, like a calibration!**

Hardware Block Diagram

Arbitrary Function Generator generates simulated AE-signals under software control.

The user connects it to the channel under test



Printer port controls parametric counter. PCTD identifies each waveform pattern in the AE data file

Functional Blocks and their Interactions

Pattern Stimulation Software "Vallen VeriStimulator"

- Controls the arbitrary function generator and the parametric counter.

Arbitrary Function Generator

- Creates test patterns under software control
- If calibrated, turns the verification into a calibration.

LPT1 Parallel Cable

- VeriStimulator controls via LPT1 and this cable the parametric counter (PCTD) of the AE-system to identify each test pattern to the verification software.

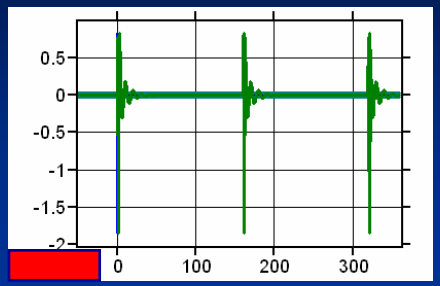
AE-System Model Vallen AMSY4 or AMSY-5

- Converts stimulated AE signals to parameter and waveform data as usual
- No difference to normal use, same acquisition software as usual
- Proper function of the software is verified, too.

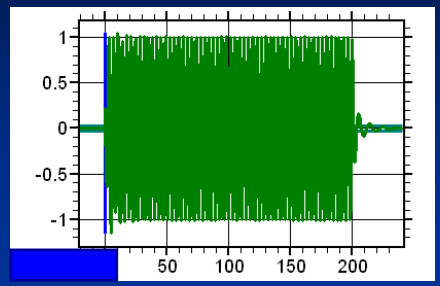
Data Verification Software "Vallen VeriAnalyzer"

- Verifies the data and creates a clear report in DOC format

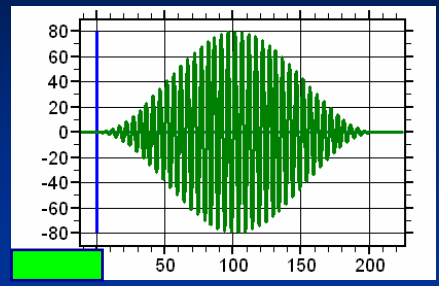
Test Signals and Test Sequence - Overview



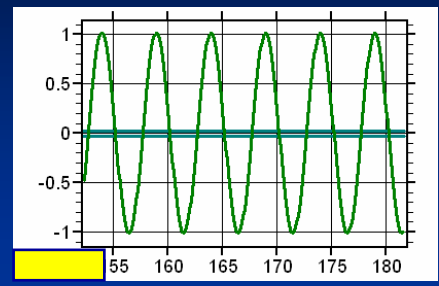
Pulses: Open/close a test



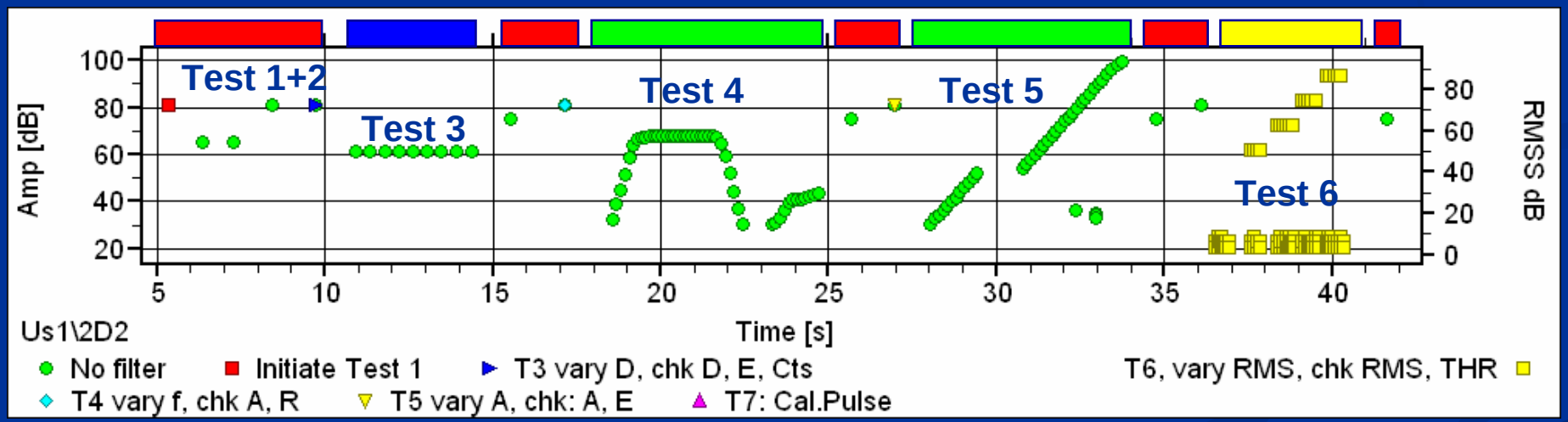
Rectangular shaped bursts



sine^2 shaped bursts



continuous sine wave



Test 1+2: checks DDT + RAT (Timings)

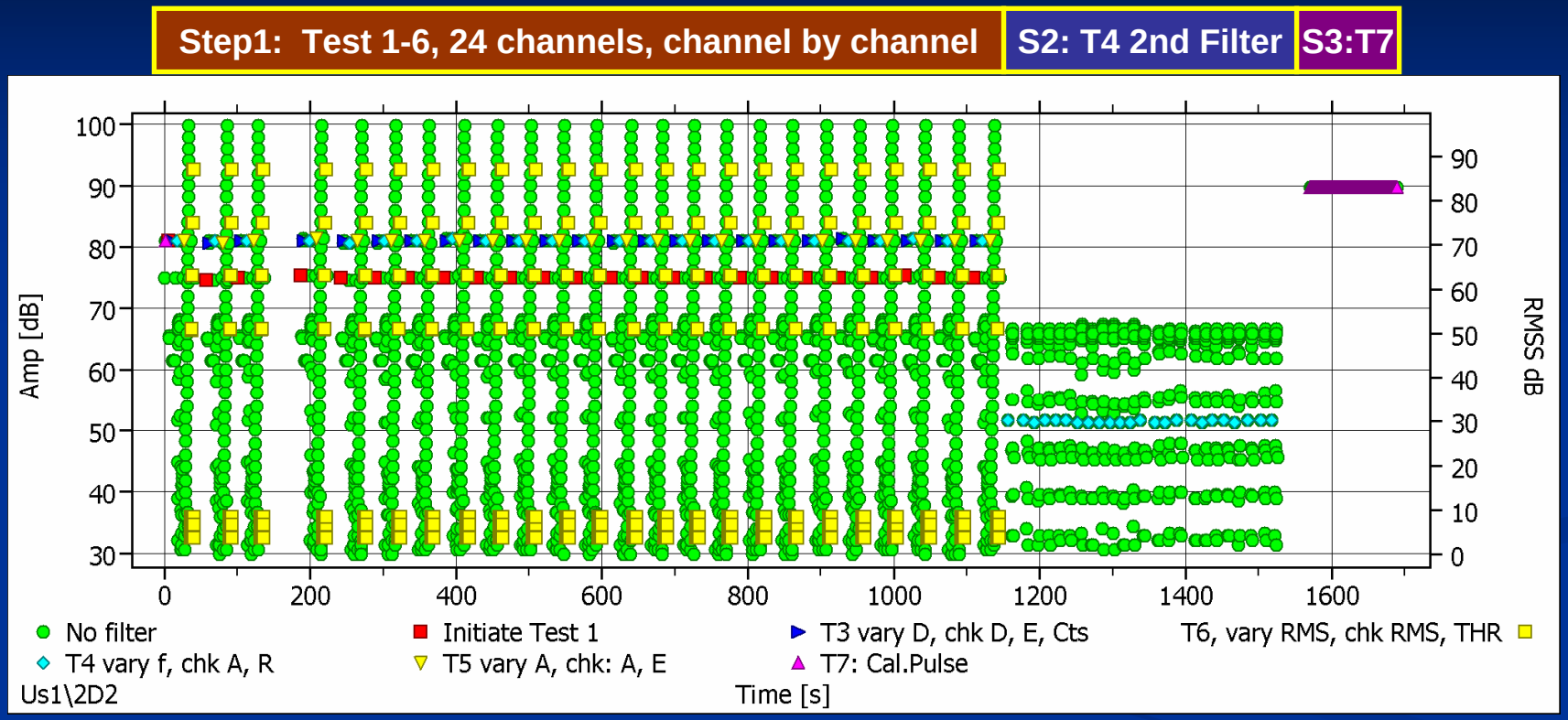
Test 3: 9 durations, checks D, E, Cts,

Test 4: 50 freqs, checks freq. response, R;

Test 5: 35 amplitudes 30 to 100 dB, to check A, E.

Test 6: 5 levels continuous sine-waves, to check RMS, floating threshold

Example: A vs. T for a 24-Channel Verification



Automated AE-channel verification is performed in three steps:

1. Tests 1-6 check all parameters with 1st band-pass filter configuration
2. Test 4 (frequency response) for additional filter, if so configured,
3. Test 7 checks functional correctness of calibration-path

Time needed for all three steps, 24 chan.: 1700 seconds, less than 30 minutes

Verification begins with the Configuration Report...

AMSY-5 ASIPP Configuration Report

VeriConfig.Template: 4/28/2004 3:20 PM Version 3.0

The contents of this document are used for the generation of one verification report per ASIPP by Y5VeriAnal

System Type	IdNo	Rad Addr	No of PA-Channels	Ref ASIPP Id	Ref ASIPP Ch No
AMSY-5 M16	42683	01	4	41814	60

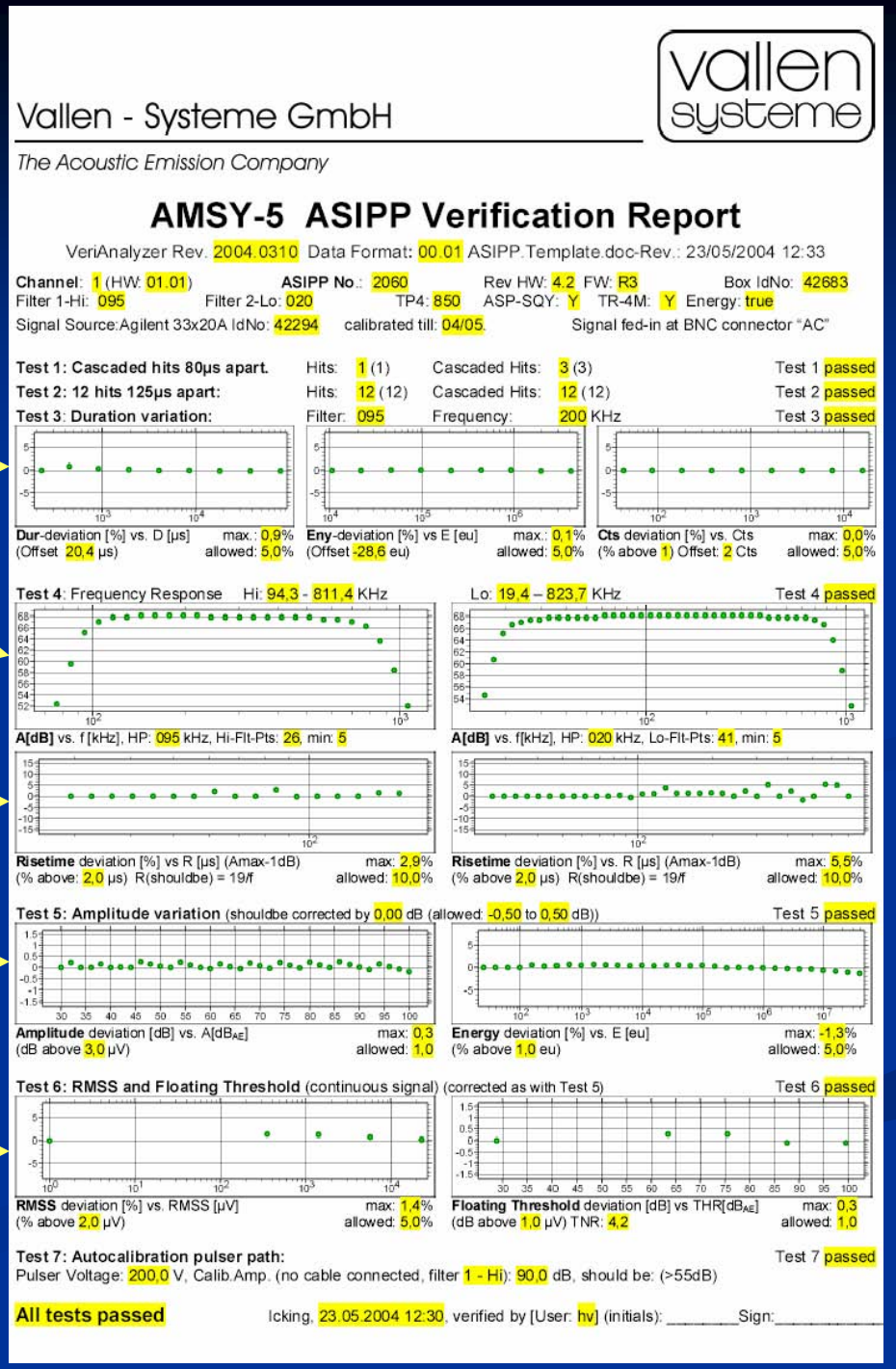
Signal Source used for PAx Input Stimulation: Analogic AN3100 IdNo: 40806 calibrated till: 06/04
Signal Source used for ASIPP-Verification: Agilent 33x20A IdNo: 42294 calibrated till: 04/05

ASIPP Chan No.	Prüf No.	Rev. HW	Rev. FW	ASP-SQ (Y/N)	OK	TR-4M (Y/N)	OK	High-Pass 1 (Hi) HP4-	High-Pass 2 (Lo) HP4- / BP-	Low-Pass TP4-	Remark	Verified
1	2060	4.2	R3	Y	✓	Y	✓	095	020	850		✓
2	2061	4.2	R3	Y	✓	N		095	020	850		✓
3	2062	4.2	R3	Y	✓	N		095	020	850		✓
4	2063	4.2	R3	Y	✓	N		095	020	850		✓
5	2064	4.2	R3	Y	✓	N		095	020	850		✓

- Report is part of system documentation, reports all configuration details of the system and each AE channel (ASIPP)
- Information is read by VeriAnalyzer and used for the verification report

Verification Report

- The yellow fields in the Verification Report are “filled in” by the Verification software.
- One page per channel contains all relevant verification information
- Frequency response diagram indicates cut-of frequencies
- “Deviation Diagrams” present the %-deviation of the measured from “should be” values.
  Maximum detected deviations and acceptance criteria
  are shown in the legends.
- For each test one field shows either “passed” or “failed”.



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AMSY-5 ASIPP Verification Report

VeriAnalyzer Rev. 2004.0310 Data Format: 00.01 ASIPP.Template.doc-Rev.: 23/05/2004 12:33

Channel: 1 (HW: 01.01) **ASIPP No.**: 2060 Rev HW: 4.2 FW: R3 Box IdNo: 42683
Filter 1-Hi: 095 Filter 2-Lo: 020 TP4: 850 ASP-SQY: Y TR-4M: Y Energy: true
Signal Source:Agilent 33x20A IdNo: 42294 calibrated till: 04/05. Signal fed-in at BNC connector “AC”

Test 1: Cascaded hits 80µs apart. Hits: 1 (1) Cascaded Hits: 3 (3) Test 1 passed
Test 2: 12 hits 125µs apart: Hits: 12 (12) Cascaded Hits: 12 (12) Test 2 passed
Test 3: Duration variation: Filter: 095 Frequency: 200 KHz Test 3 passed

Dur-deviation [%] vs. D [µs] max.: 0,9%
(Offset 20,4 µs) allowed: 5,0%

Eny-deviation [%] vs E [eu] max.: 0,1%
(Offset -28,6 eu) allowed: 5,0%

Cts deviation [%] vs. Cts max: 0,0%
(% above 1) Offset: 2 Cts allowed: 5,0%

Test 4: Frequency Response Hi: 94,3 - 811,4 KHz Lo: 19,4 – 823,7 KHz Test 4 passed

A[dB] vs. f [kHz], HP: 095 kHz, Hi-Flt-Pts: 26, min: 5

A[dB] vs. f [kHz], HP: 020 kHz, Lo-Flt-Pts: 41, min: 5

Risetime deviation [%] vs R [µs] (Amax-1dB) max: 2,9%
(% above: 2,0 µs) R(shouldbe) = 19/f allowed: 10,0%

Risetime deviation [%] vs. R [µs] (Amax-1dB) max: 5,5%
(% above 2,0 µs) R(shouldbe) = 19/f allowed: 10,0%

Test 5: Amplitude variation (shouldbe corrected by 0,00 dB (allowed: -0,50 to 0,50 dB)) Test 5 passed

Amplitude deviation [dB] vs. A[dB_{AE}] max: 0,3
(dB above 3,0 µV) allowed: 1,0

Energy deviation [%] vs. E [eu] max: -1,3%
(% above 1,0 eu) allowed: 5,0%

Test 6: RMSS and Floating Threshold (continuous signal) (corrected as with Test 5) Test 6 passed

RMSS deviation [%] vs. RMSS [µV] max: 1,4%
(% above 2,0 µV) allowed: 5,0%

Floating Threshold deviation [dB] vs THR[dB_{AE}] max: 0,3
(dB above 1,0 µV) TNR: 4,2 allowed: 1,0

Test 7: Autocalibration pulser path: Test 7 passed
Pulser Voltage: 200,0 V, Calib.Amp. (no cable connected, filter 1 - Hi): 90,0 dB, should be: (>55dB)

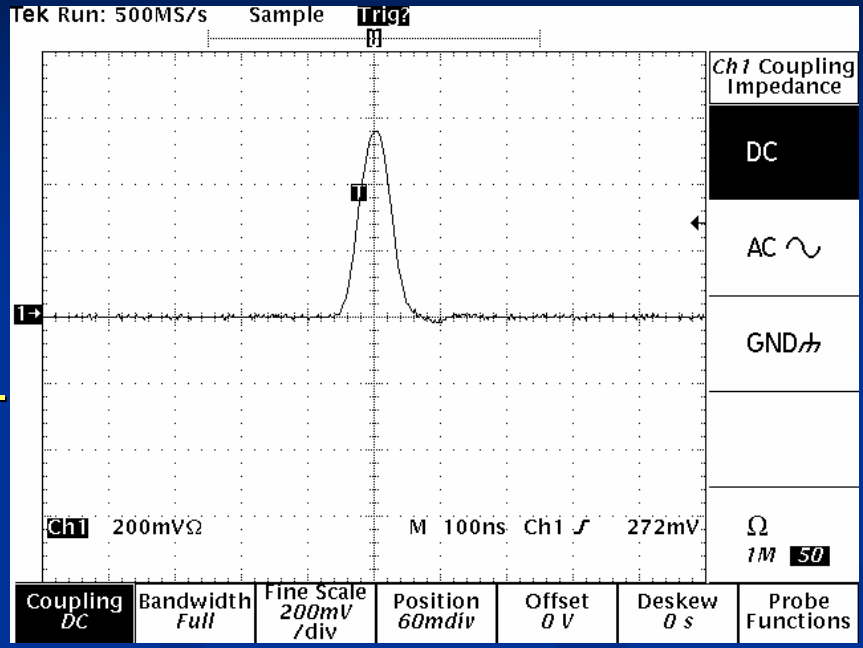
All tests passed Icking, 23.05.2004 12:30, verified by [User: hv] (initials): _____ Sign: _____

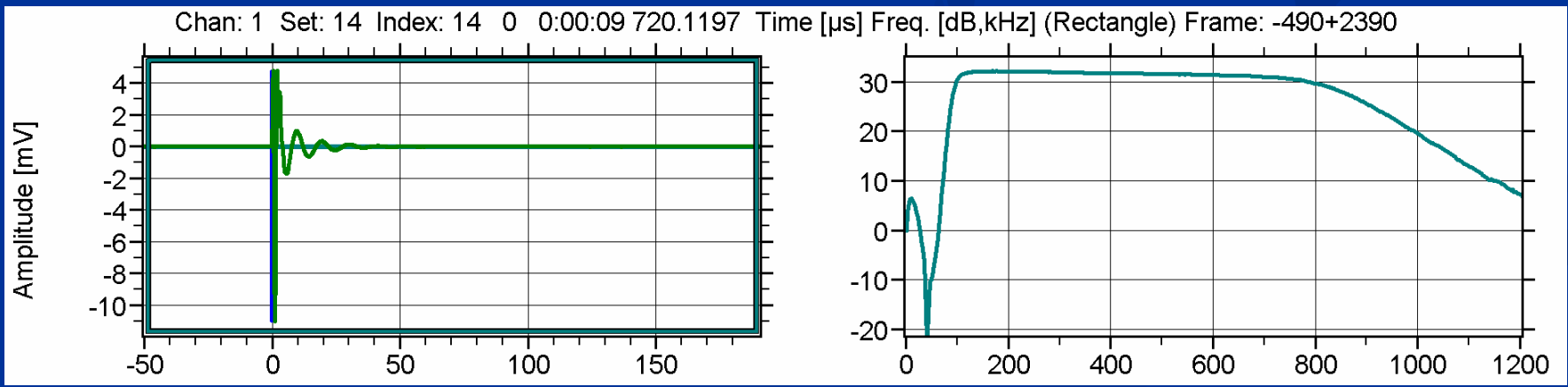
Test Signal Details

Wide-band test signal: Dirac pulse

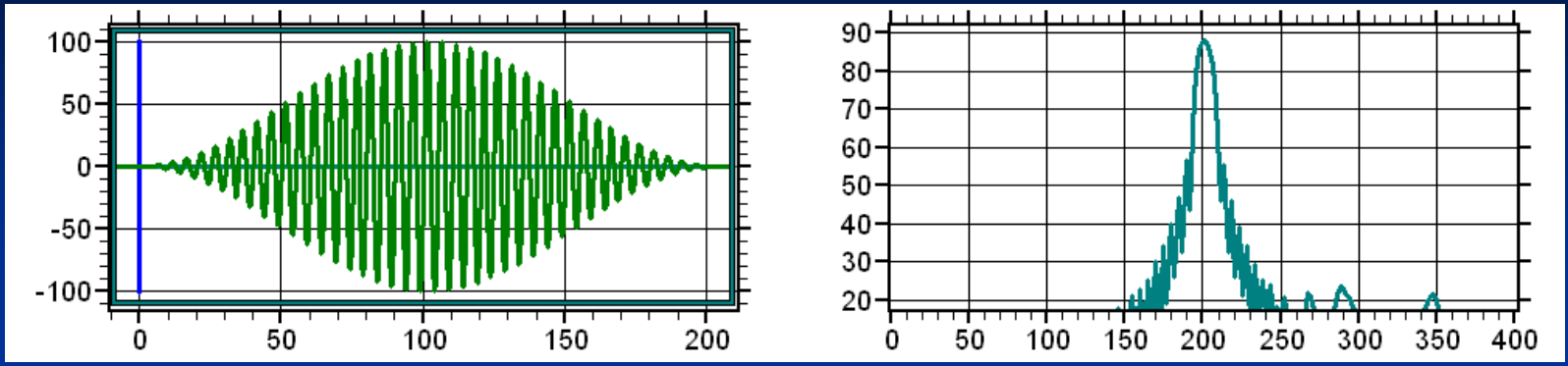
A 50 ns pulse, fed through a 95-850kHz band-pass filter produces the waveform below.

This signal passes through any band-pass configuration. It is used to force hits for timing tests or to pass e.g. test-number information to the verification software.

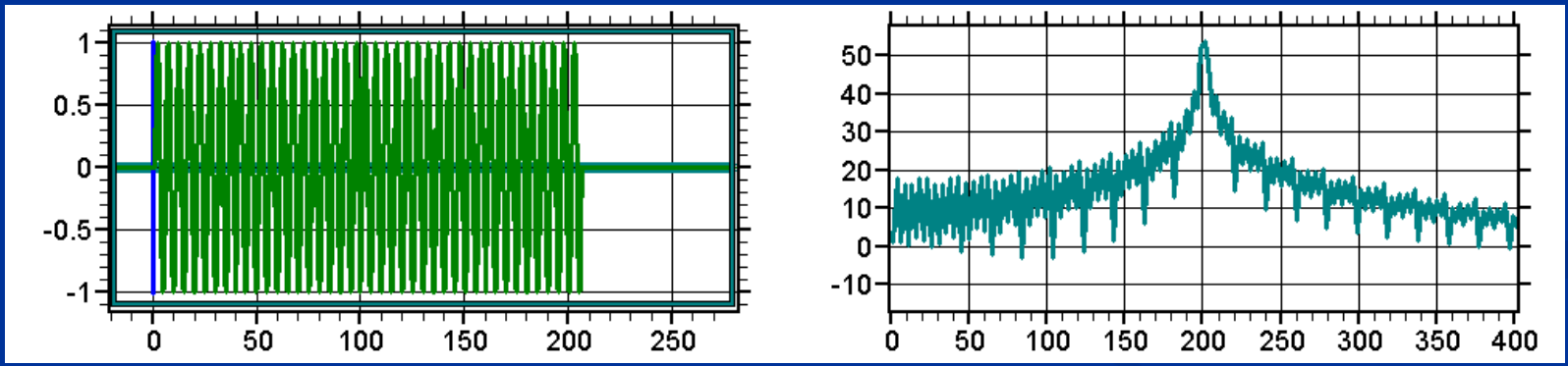




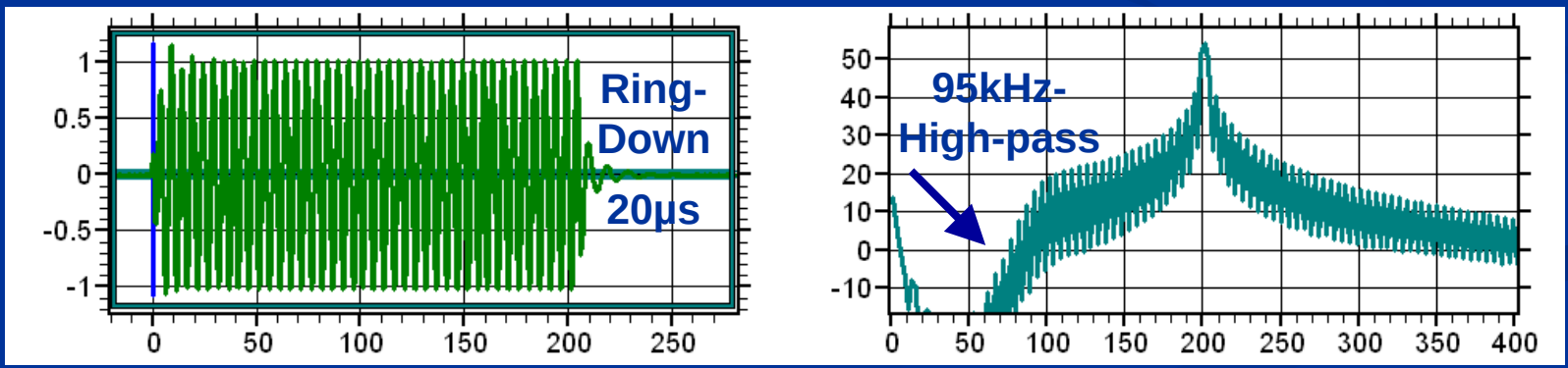
Sine Wave Bursts, Sine^2 and rectangular shaped



Sine wave burst, Sine^2 shaped (FFT in dB vs kHz) "purest freq"



sine-wave burst, rectangular shaped (no filter, calculated)



Sine wave burst, rectangular shaped (95-850kHz, measured)

Test 3: Duration Variation – Example for Pattern Identif.

DSET	CHAN	PCTD	A	R	D	E	CNTS	Comment:
			[dB]	[µs]	[µs]	[eu]		
633	1	**18**	81,0	1,2	42,8	885E01	5	**Dirac: Open**
744	1	**70**	61,4	9,0	225,4	106E02	43	Pattern **#1**
817	1	72	61,4	9,0	449,6	219E02	88	Pattern #2
891	1	74	61,4	9,0	919,6	462E02	182	Pattern #3
971	1	76	61,4	9,0	1919,2	979E02	382	Pattern #4
1053	1	78	61,4	9,0	4024,0	207E03	802	Pattern #5
1126	1	80	61,4	9,0	8483,2	437E03	1695	Pattern #6
1199	1	82	61,4	9,0	17907,2	925E03	3580	Pattern #7
1290	1	84	61,1	9,0	37836,8	195E04	7568	Pattern #8
1362	1	**86**	61,4	9,0	80000,0	413E04	16000	Pattern **#9**
1492	1	**2**	75,0	1,2	36,4	220E01	4	**Dirac: Close**

PCTD =18 opens Test 3 (information from stimulator to verifier software),

PCTD= 2 closes each test.

PCTD = 70..86 identify the individual patterns of this test.

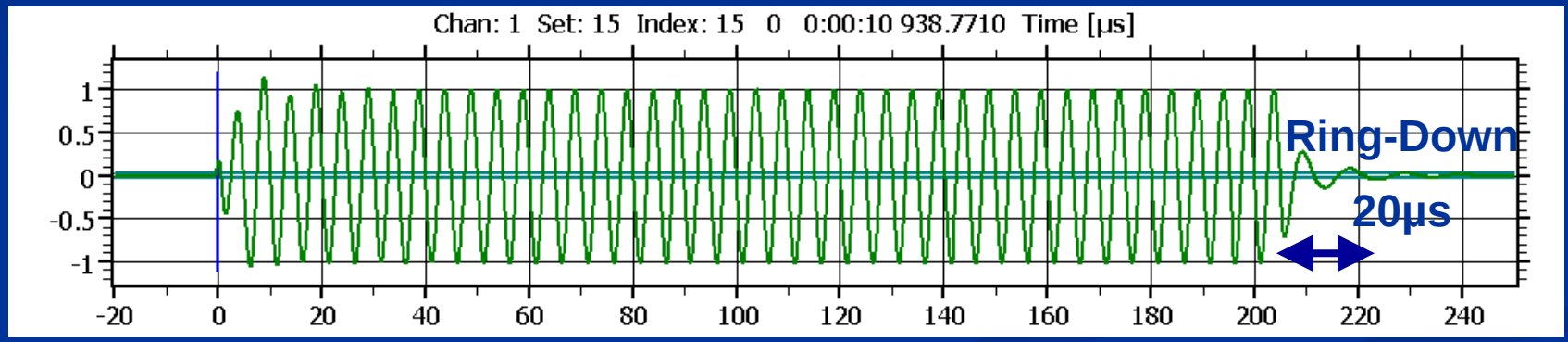
VeriAnalyzer converts the identifier PCTD to “should be values”.

This test is used to verify D, E, CNTS.

Artefacts and Solutions

Test 3: Duration Variation – Ring Down Problem

DSET	CHAN	PCTD	A [dB]	R [µs]	D [µs]	E [eu]	CNTS	Comment:
633	1	18	81,0	1,2	42,8	885E01	5	Dirac: Open
744	**1**	**70**	**61,4**	**9,0**	**225,4**	**106E02**	**43**	**Pattern #1**
817	1	72	61,4	9,0	449,6	219E02	88	Pattern #2



Problem:

Duration:	"Should be":	205 µs	measured: 225,4 µs	→Offset:	20,2 µs
Counts:	"Should be":	41	measured: 43	→Offset:	2
Energy:	"Should be":	10420 eu	measured: 10555 eu	→Offset:	135 eu

Reason:

Ring-Down-Effect. Ring down is constant for all durations, so it can be compensated.

Solution:

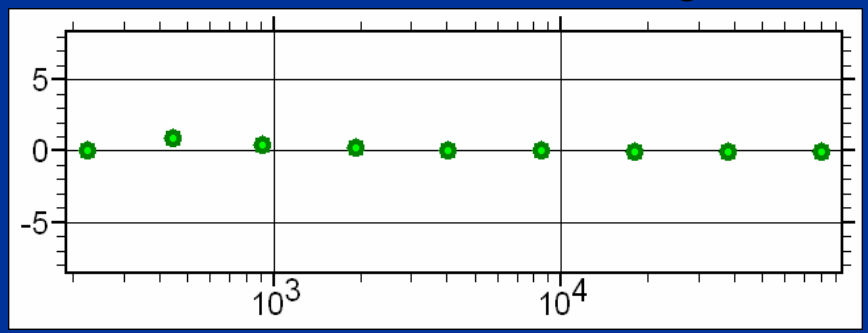
Difference "measured value" – "should be value" of shortest duration pattern is used as an offset to correct the other measurements within this test.

Test 3: Duration Variation – Deviation Diagrams

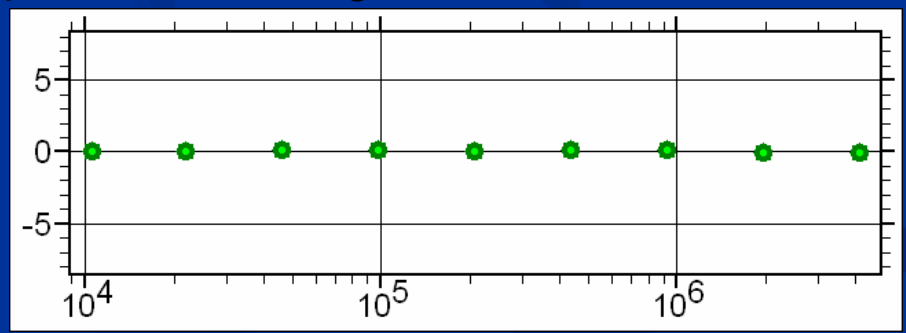
DSET	CHAN	PCTD	A [dB]	R [µs]	D [µs]	E [eu]	CNTS	Comment:
744	1	70	61,4	9,0	225,4	106E02	43	Pattern #1
817	1	72	61,4	9,0	449,6	219E02	88	Pattern #2
891	1	74	61,4	9,0	919,6	462E02	182	Pattern #3
971	1	76	61,4	9,0	1919,2	979E02	382	Pattern #4
1053	1	78	61,4	9,0	4024,0	207E03	802	Pattern #5
1126	1	80	61,4	9,0	8483,2	437E03	1695	Pattern #6
1199	1	82	61,4	9,0	17907,2	925E03	3580	Pattern #7
1290	1	84	61,1	9,0	37836,8	195E04	7568	Pattern #8
1362	1	86	61,4	9,0	80000,0	413E04	16000	Pattern #9

Deviation Diagrams and Legends (2 of 3) in the Verification Report:

The “Offset” in the legends compensates the ring-down effect.

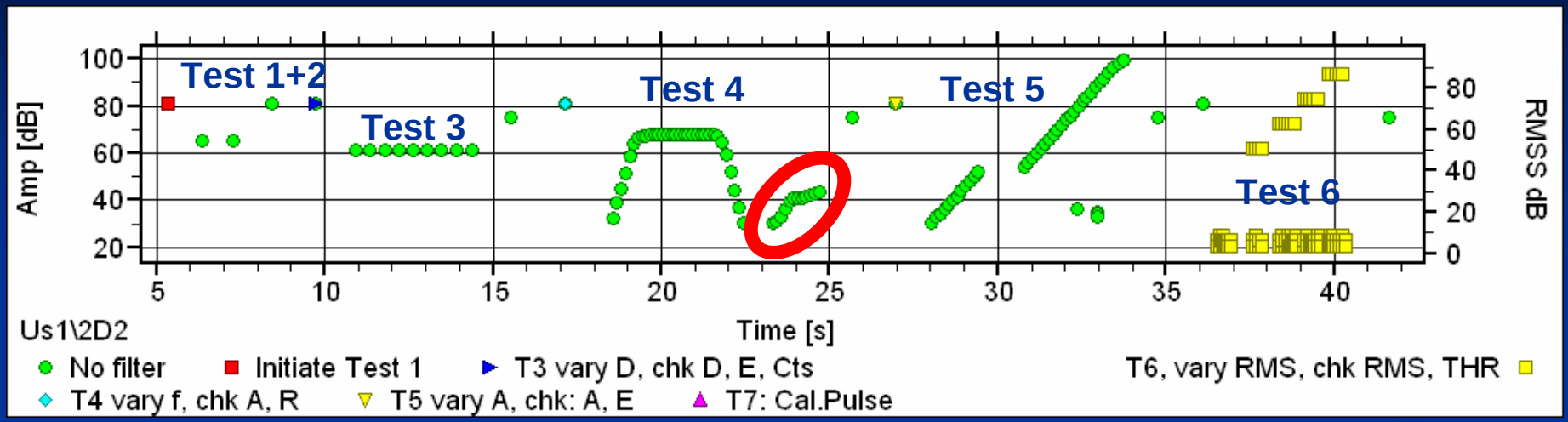


Dur-deviation [%] vs. D [µs] max.: 0,9%
(Offset 20.4 µs) **allowed: 5,0%**

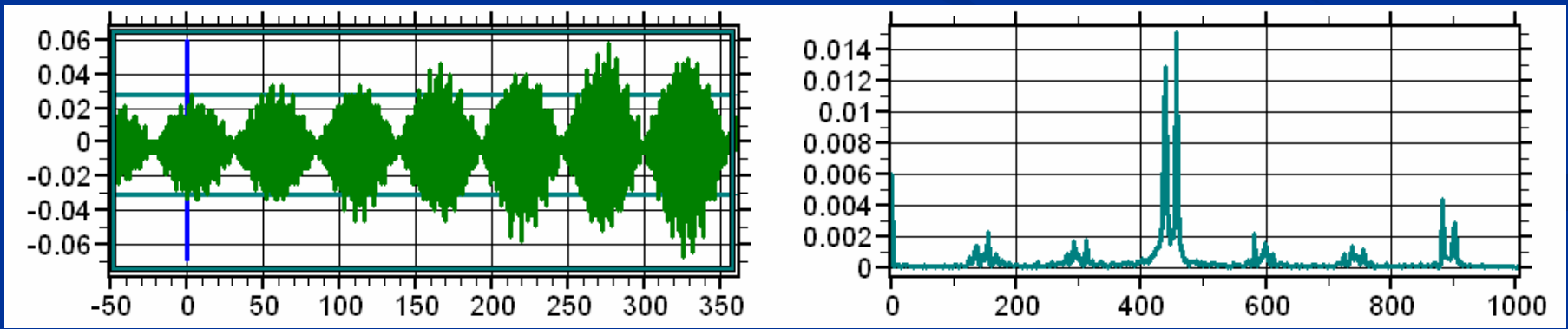


Eny-deviation [%] vs E [eu] max.: 0,1%
(Offset 135 eu) **allowed: 5,0%**

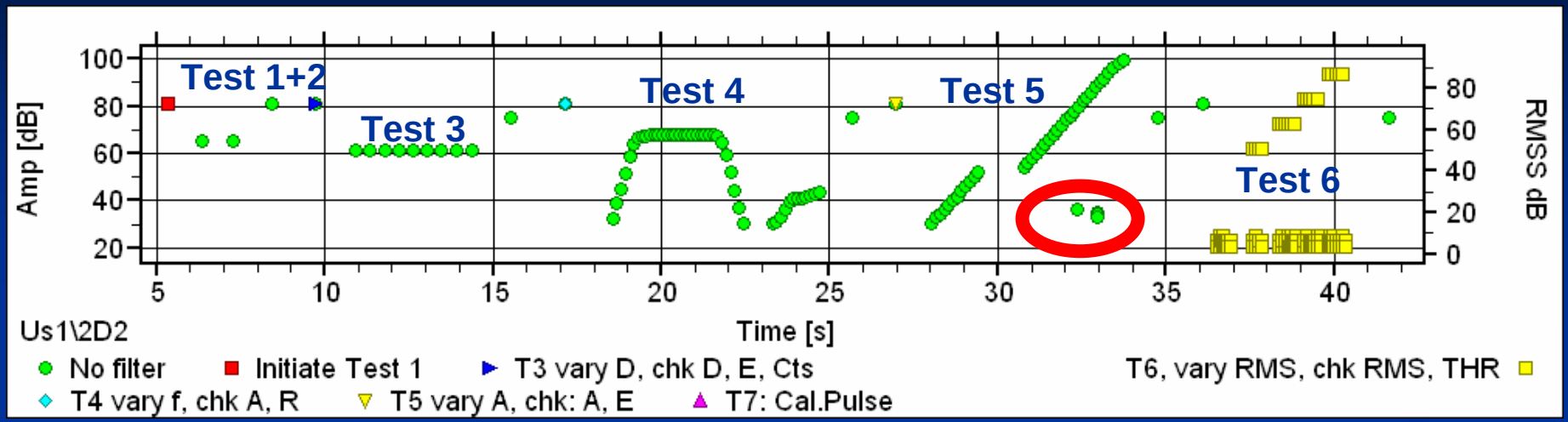
Test 4: Artefact in Frequency Response



Test 4 starts with 1.5MHz (sine-squared shape), decreasing by 10% per burst.
The increase of amplitude at frequencies below the band-width is an artefact.
Reason: AFG produces frequency impurities. Solution: None, does not disturb.



Test 5: Amplitude Variation – Noise Contamination



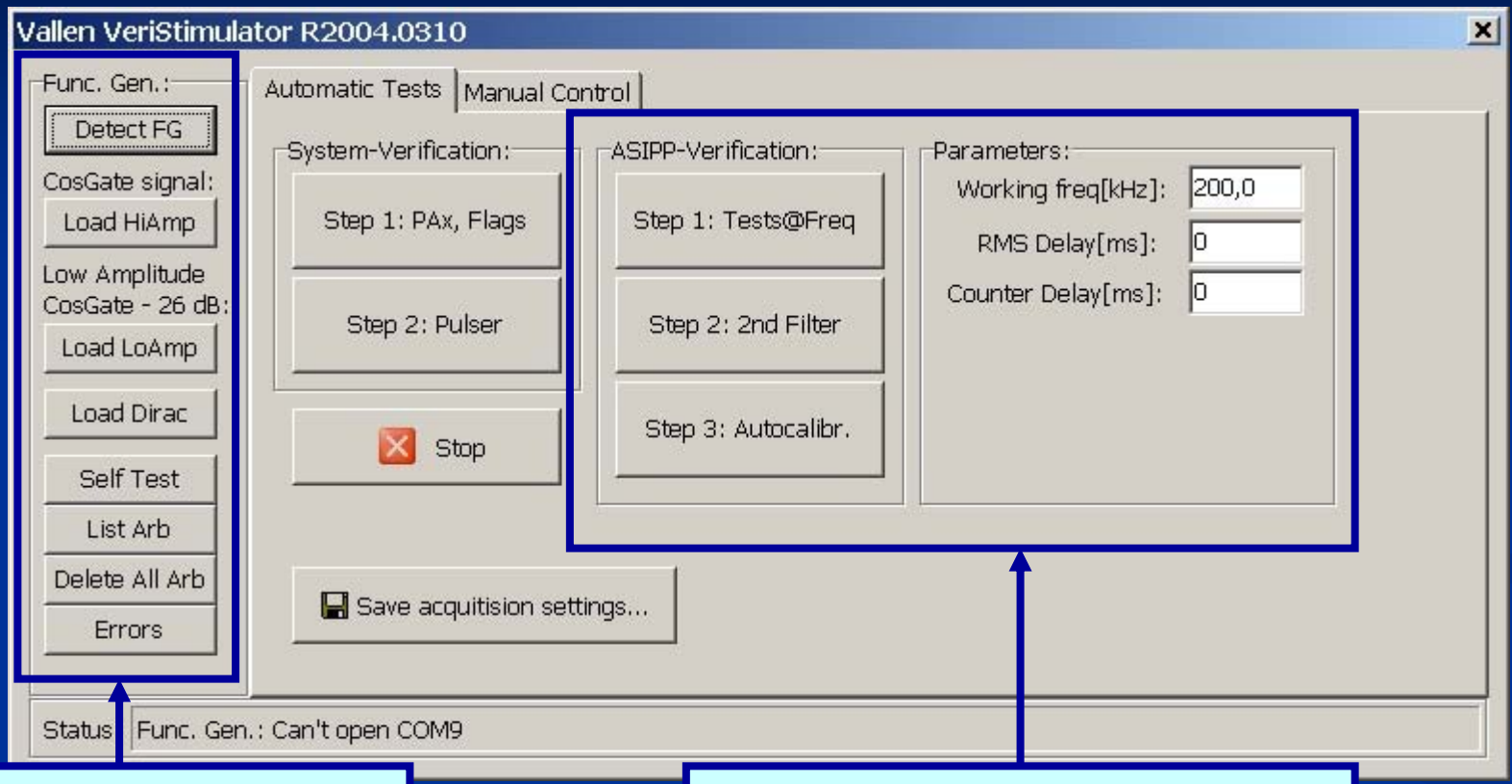
Problem: False hits triggered by noise of function generator.
(Threshold is constant 28dB over the Test 1 to 5)

Solution: Noise is eliminated in the verification process by selecting the last hit of a PCTD-value (Identifier)

DSET	CHAN	PCTD	A [dB]	R [µs]	D [µs]	E [eu]	CNTS	
3912	1	138	78,0	97,6	196,2	248E03	39	
3931	1	**140**	**30,6**	0,2	15,0	882E-3	1	←A=30,6dB
3933	1	**140**	**80,2**	97,8	196,4	392E03	39	
3969	1	142	82,1	97,8	198,6	622E03	40	

Operation is very easy and straight forward

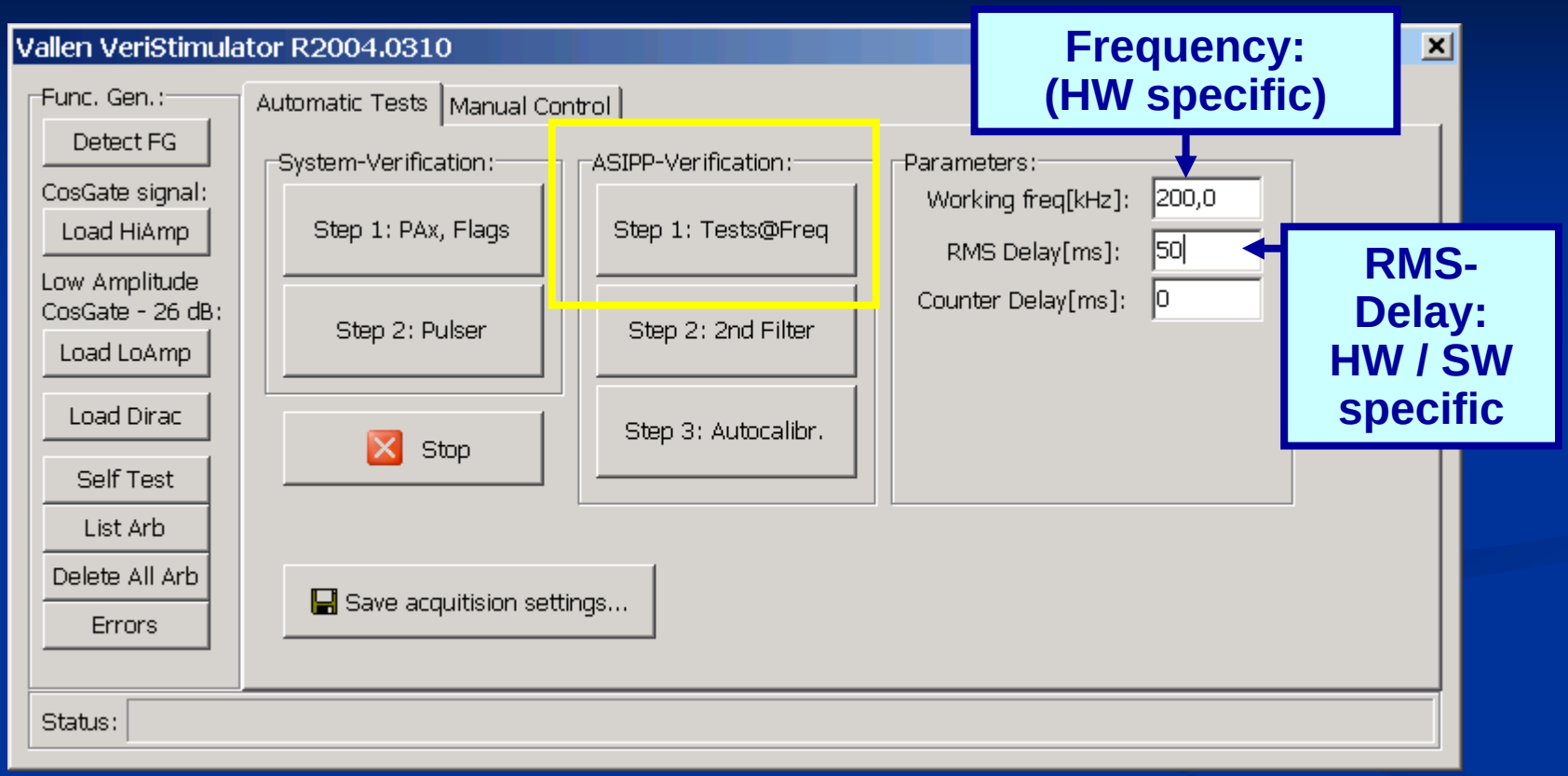
Vallen VeriStimulator in Automatic Mode



For verification and programming of function generator

User - interface for automated AE-channel verification

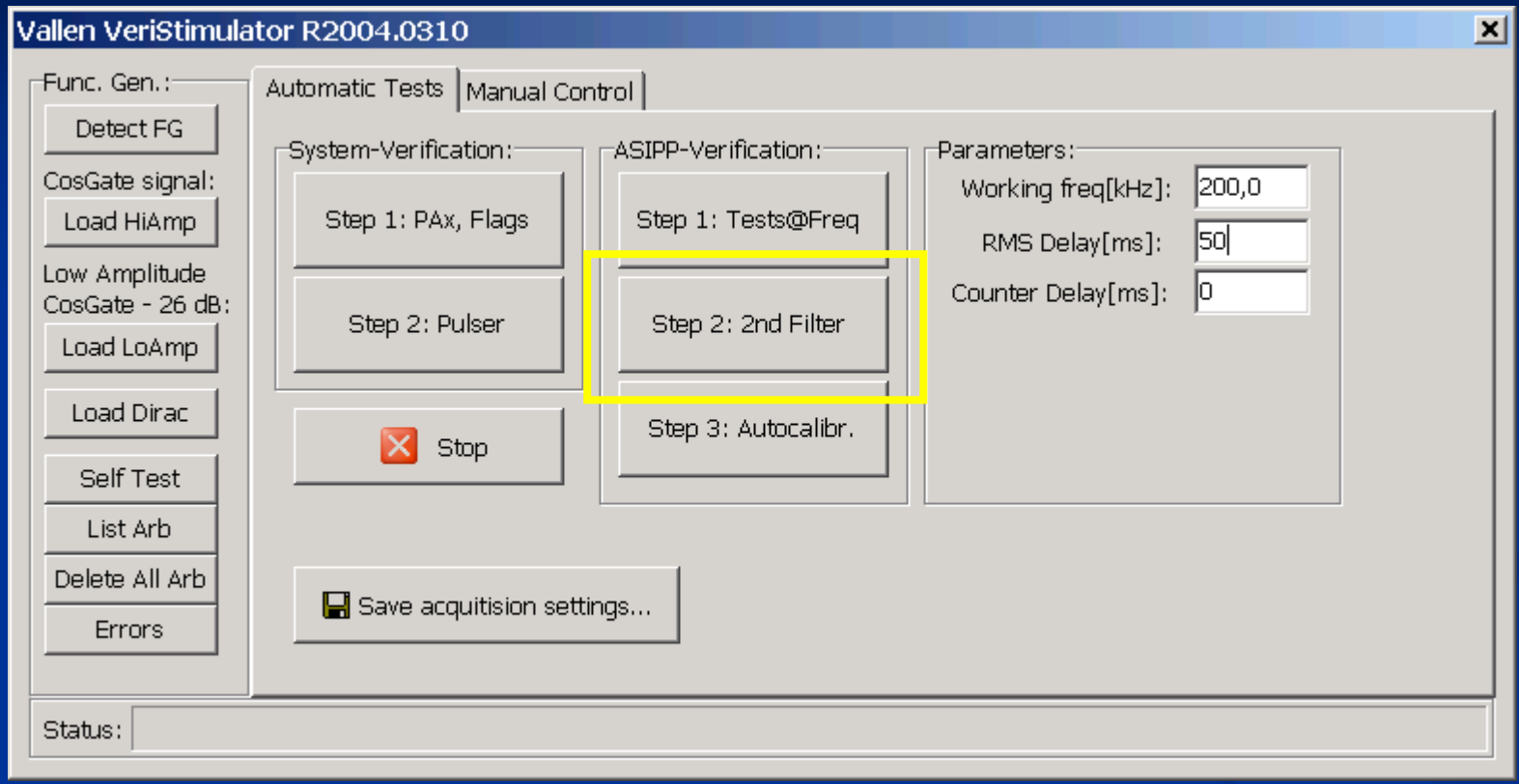
AE-Channel Verification - Step 1



Step 1 (performed channel by channel)

- Varies all parameters at working frequency (mid of band-pass) (Test1-3,5)
- Varies frequency for verification of band-pass characteristics (Test 4)
- Varies continuous sine wave level for RMS and floating threshold test (Test 6)

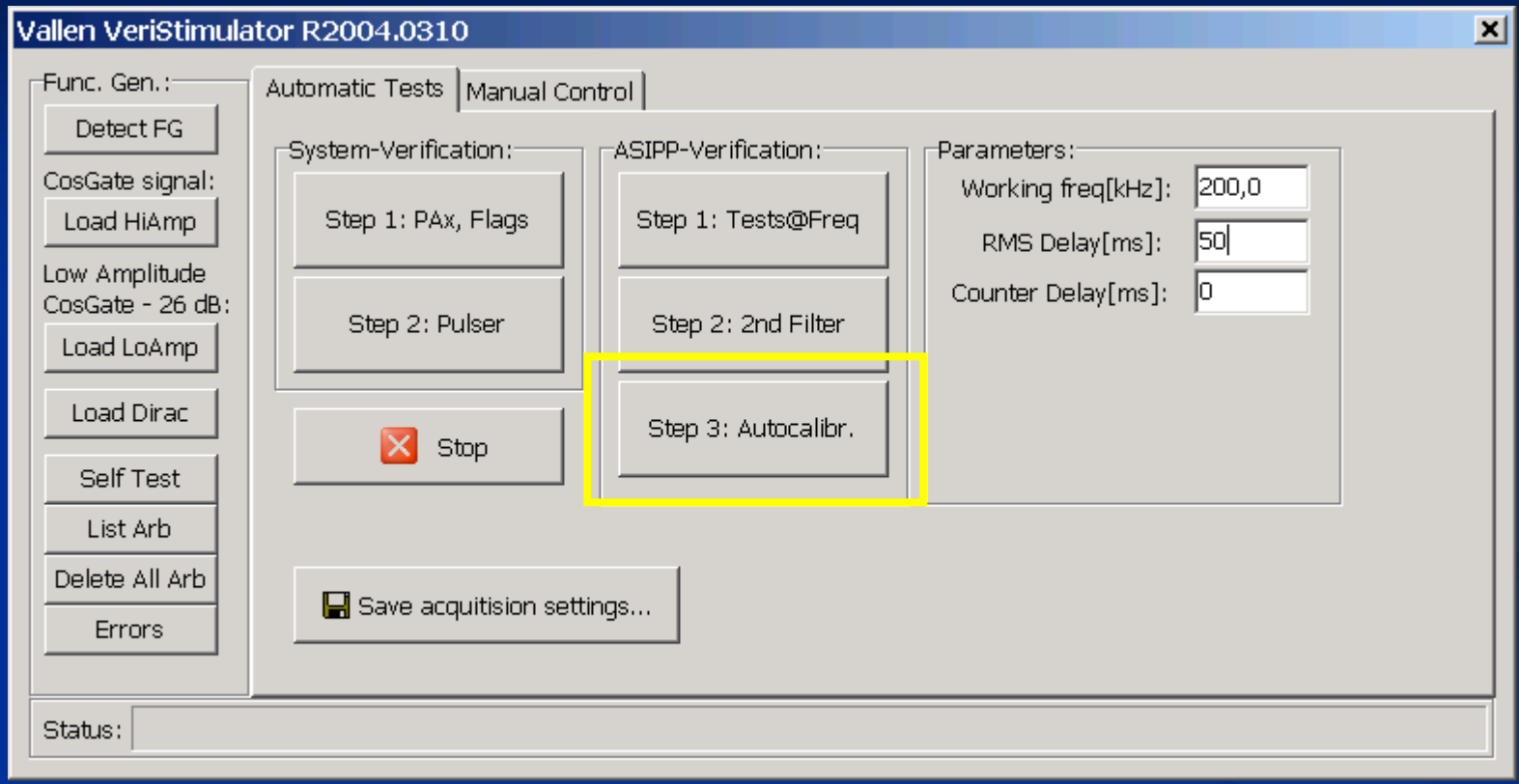
AE-Channel Verification - Step 2



Step 2 (performed channel by channel)

- Varies frequency for verification of 2nd band-pass characteristics, if any (Test 4)

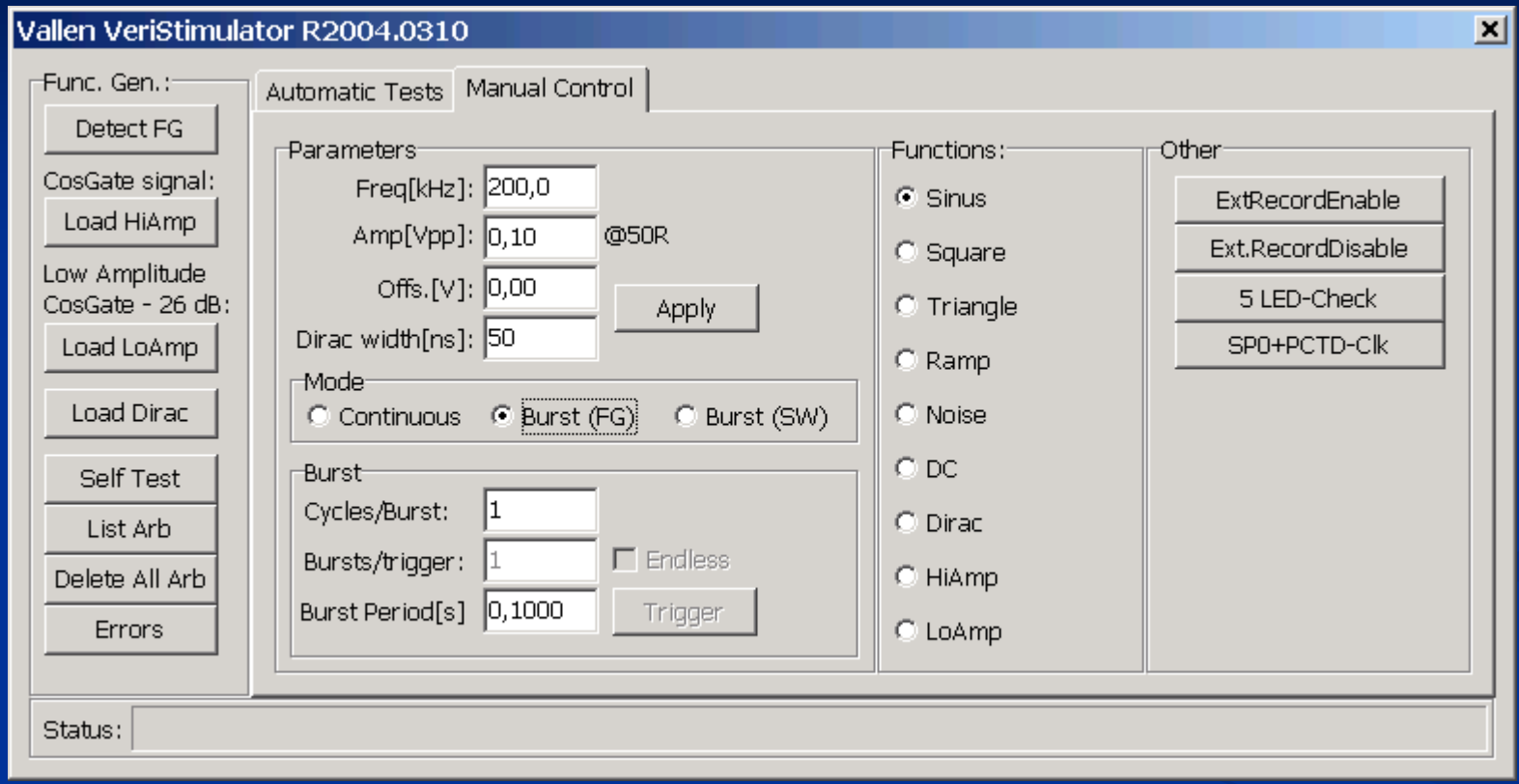
AE-Channel Verification - Step 3



Step 3:

- Sends calibration pulse through the AE channel for functional verification, channel by channel, automated

Vallen VeriStimulator in Manual Control Mode

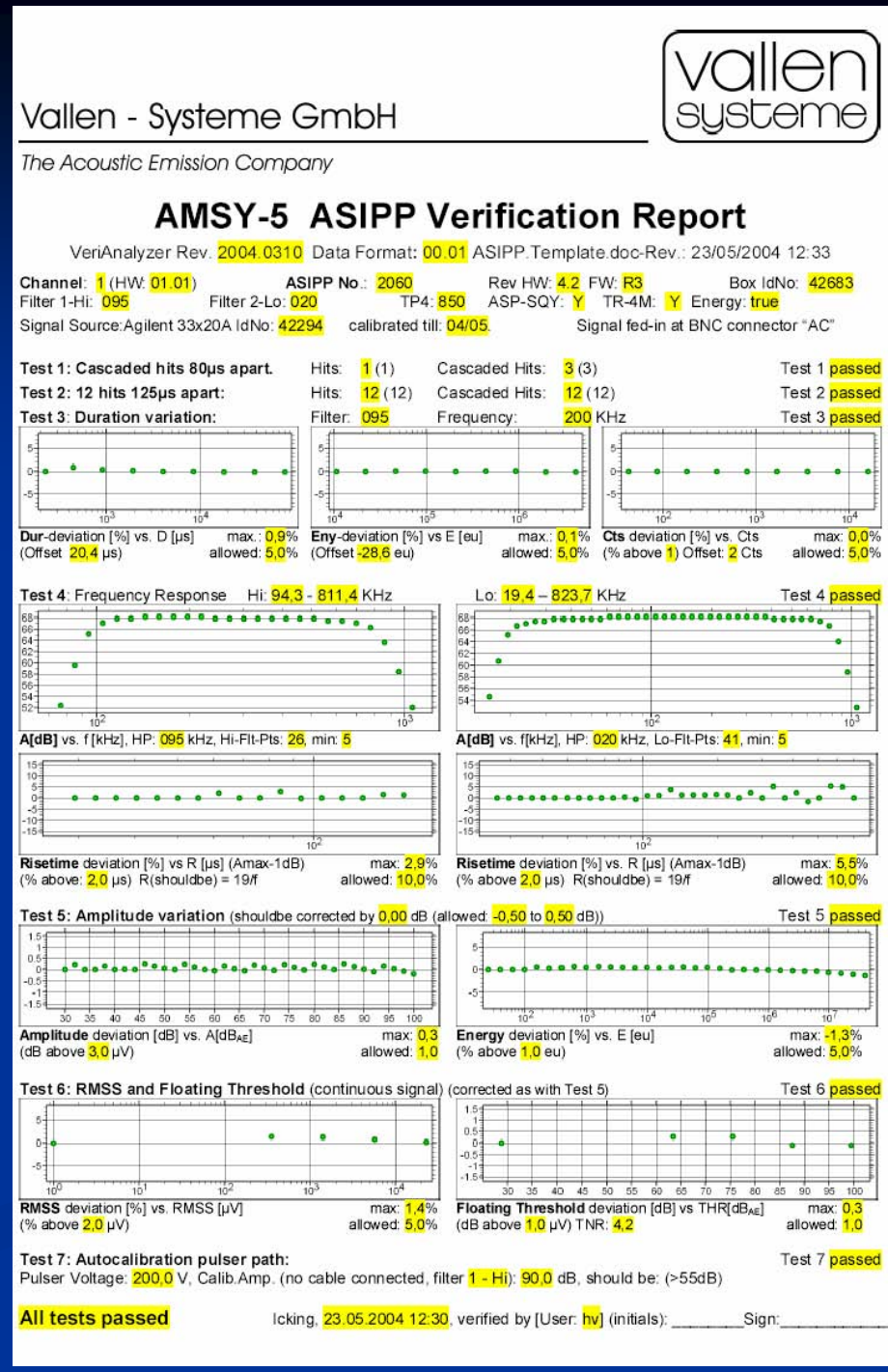


Function generator can be used like an AE-calibrator

Closing Remarks

Closing Remarks

- Verification of AE-equipment is a disliked job, many try to avoid it, many spend lot of money for calibration.
- The automated **Vallen Verification Process** is very easy to operate, saves time, and provides evidence by document, that the instrument complies to the specifications.
- The **Vallen Verification Process** far exceeds the requirements of EN13477-2. Using a calibrated arbitrary function generator, the **Vallen Verification Process** performs a traceable calibration.
- The **Vallen Verification Process** is another effort to build up trust into the AE method and the tools and equipment used.



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The Acoustic Emission Company

AMSY-5 ASIPP Verification Report

VeriAnalyzer Rev. 2004.0310 Data Format: 00.01 ASIPP.Template.doc-Rev.: 23/05/2004 12:33

Channel: 1 (HW: 01.01) **ASIPP No.**: 2060 Rev HW: 4.2 FW: R3 Box IdNo: 42683
Filter 1-Hi: 095 Filter 2-Lo: 020 TP4: 850 ASP-SQY: Y TR-4M: Y Energy: true
Signal Source:Agilent 33x20A IdNo: 42294 calibrated till: 04/05. Signal fed-in at BNC connector "AC"

Test 1: Cascaded hits 80µs apart. Hits: 1 (1) Cascaded Hits: 3 (3) Test 1 passed
Test 2: 12 hits 125µs apart: Hits: 12 (12) Cascaded Hits: 12 (12) Test 2 passed
Test 3: Duration variation: Filter: 095 Frequency: 200 KHz Test 3 passed

Dur-deviation [%] vs. D [µs] max.: 0,9%
(Offset 20,4 µs) allowed: 5,0%

Eny-deviation [%] vs E [eu] max.: 0,1%
(Offset -28,6 eu) allowed: 5,0%

Cts deviation [%] vs. Cts max: 0,0%
(% above 1) Offset: 2 Cts allowed: 5,0%

Test 4: Frequency Response Hi: 94,3 - 811,4 KHz Lo: 19,4 – 823,7 KHz Test 4 passed

A[dB] vs. f [kHz], HP: 095 kHz, Hi-Flt-Pts: 26, min: 5

A[dB] vs. f[kHz], HP: 020 kHz, Lo-Flt-Pts: 41, min: 5

Risetime deviation [%] vs R [µs] (Amax-1dB) max: 2,9%
(% above: 2,0 µs) R(shouldbe) = 19/f allowed: 10,0%

Risetime deviation [%] vs. R [µs] (Amax-1dB) max: 5,5%
(% above 2,0 µs) R(shouldbe) = 19/f allowed: 10,0%

Test 5: Amplitude variation (shouldbe corrected by 0,00 dB (allowed: -0,50 to 0,50 dB)) Test 5 passed

Amplitude deviation [dB] vs. A[dB_{AE}] max: 0,3
(dB above 3,0 µV) allowed: 1,0

Energy deviation [%] vs. E [eu] max: -1,3%
(% above 1,0 eu) allowed: 5,0%

Test 6: RMSS and Floating Threshold (continuous signal) (corrected as with Test 5) Test 6 passed

RMSS deviation [%] vs. RMSS [µV] max: 1,4%
(% above 2,0 µV) allowed: 5,0%

Floating Threshold deviation [dB] vs THR[dB_{AE}] max: 0,3
(dB above 1,0 µV) TNR: 4,2 allowed: 1,0

Test 7: Autocalibration pulser path: Test 7 passed
Pulser Voltage: 200,0 V, Calib.Amp. (no cable connected, filter 1 - Hi): 90,0 dB, should be: (>55dB)

All tests passed Icking, 23.05.2004 12:30, verified by [User: hv] (initials): _____Sign:_____