Application Note

COMPARISON OF COMMERCIAL SOLUTIONS FOR JITTER AND NOISE SEPARATION

Products:

- ► R&S®RTO
- ► R&S®RTP
- ► R&S®RTO-K133
- ► R&S®RTO-K134
- ► R&S®RTP-K133
- ► R&S®RTP-K134

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1 Introduction

Jitter and noise are the limiting signal degradation factors that influence the throughput and reliability of wired transmissions. By using jitter and noise separation algorithms to detail the individual contributions, it is possible to derive measures to help improve circuit designs. Jitter and noise separation provides insight into the impact of individual jitter and noise components on a given communication link while helping developers to isolate the physical sources of any issues in their systems. It can also reveal how much improvement can be expected by solving the discovered problems.

Jitter and noise analysis represent one of the basic pillars of signal integrity measurements on high-speed interfaces. Such analysis can be used in research, development, compliance and debugging environments. It is also an essential part of compliance testing since modern high-speed interface standards specify the maximum total jitter at a defined bit error rate along with limits for individual jitter components.

In the past, jitter and noise analysis used a simple model that was not sufficiently accurate for various corner cases and thus required more and more patches. Using this algorithmic approach, the desired results can be achieved by just setting the applicable configuration options.

Rohde & Schwarz has developed a new and unique jitter and noise decomposition algorithm from the ground up. This algorithm is based on traceable modeling of the signal to alleviate the above-mentioned concerns. It can provide a reasonable decomposition in scenarios where previous algorithms struggle, while matching their results in cases where they already provide satisfactory measurement results.

The new jitter and noise decomposition algorithm can be deployed on Rohde & Schwarz RTO and RTP oscilloscopes with the R&S® RTP-K133 jitter and R&S® RTP-K134 jitter & noise decomposition options. This new software provides additional and valuable decomposition results and improves the measurement accuracy and reliability with significantly less data. Moreover, it is easier to use than ever before.

This paper evaluates the performance of the Rohde & Schwarz jitter decomposition algorithm vs. other commercially available solutions. Despite the different approach used by the new jitter analysis option, the results are both comparable and consistently more accurate than other solutions available on the market under various jitter conditions. Along with this comparison, the paper also focuses on the precision of the decomposition in the different jitter solutions.

The paper is structured as follows: Chapter 2 describes the individual jitter components. Chapter 3 discusses signal generation for the jittered waveforms used as inputs to the decomposition algorithms. Chapter 4 discusses the jitter analysis frameworks used by Rohde & Schwarz and competing oscilloscope vendors. Chapter 5 presents the jitter test results for various jittered signals that were analyzed using all of the different oscilloscope solutions. Chapter 6 analyzes the consistency of the decomposition for different jitter solutions. Chapter 7 summarizes the conclusions of the paper.

2 Types of jitter

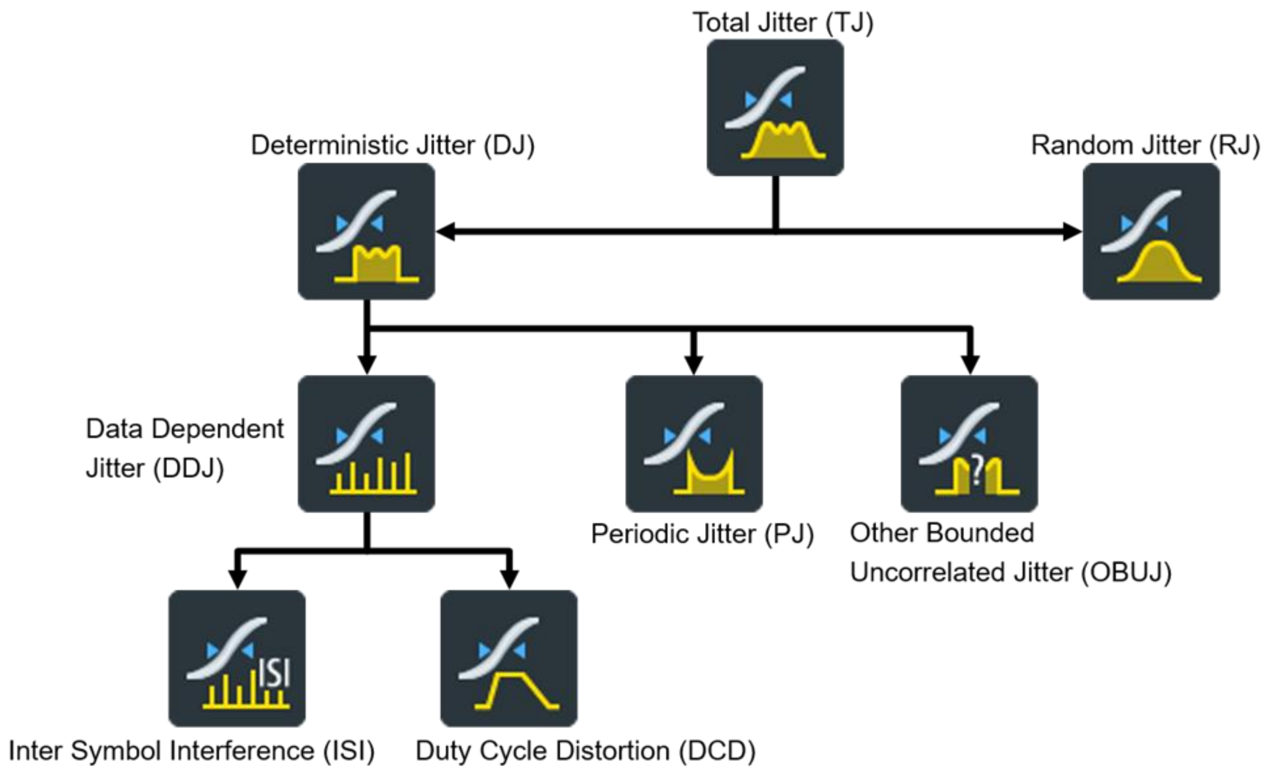


Fig. 2-1: Jitter decomposition tree

The overall jitter of an acquired signal waveform is measured in the form of the time interval error (TIE) which is commonly known as the total jitter (TJ). This is composed of a random jitter (RJ) component due to thermal noise (generally Gaussian in nature), shot noise and pink noise and a deterministic jitter (DJ) component due to systematic occurrences in a design. DJ contains periodic jitter impairments (PJ) that can originate, for example, in switching power supplies, oscillators and instable PLL circuits. Data dependent jitter (DDJ) due to the finite channel bandwidth (which can also be expressed as the system step response) includes transmission losses and other bounded but uncorrelated jitter (OBUJ) caused by crosstalk.

Additionally, DDJ can be split further into one component that captures the impact of all step responses, e.g. rising and falling inter symbol interference (ISI), which may occur due to bandwidth limitations in the transmitter, receiver or physical media, or asymmetries in the rise/fall times of the signal. The other component (duty cycle distortion or DCD) represents the differences between rise and fall times or a threshold error leading to one bit polarity having a longer unit interval than the other.

Since many of the advanced capabilities of the new Rohde & Schwarz algorithm are not available in the competitors' solutions, they are not considered in this analysis in order to provide fair grounds for comparison. Such features include the entire noise analysis, all vertical impairments in signals used for jitter analysis, decomposition of source domain values, etc. A more complete overview of the test setup is provided in the following chapters.

3 Signal generation environment

This chapter briefly discusses the reason for using a signal model along with the signal generation environment based on the signal model [1]. As explained in [1], the Rohde & Schwarz jitter and noise signal model expression contains all components necessary to construct the desired device under test (DUT) signal. Using an appropriate signal generation environment gives us the freedom to individually turn on/off or modify all of the disturbance components. Thus, it becomes possible to analyze a variety of jitter disturbances.

There are several reasons for using a software based signal generation environment instead of a real-world signal from a DUT, a bit error rate tester (BERT) or some other device that generates analog signals. All real-world signals must pass through the oscilloscope's analog front-end amplifier, which adds noise and distortion to the signal due to non-linearity. This makes it difficult to distinguish effects caused by the front-end amplifiers of the different oscilloscopes or the vendor's jitter decomposition solutions.

Any DUT is unpredictable in terms of RJ, PJ and ISI since there is no golden device. Even just connecting to the device will change the DDJ due to the frequency response of the connection setup.

Only a BERT is able to arbitrarily set parameters such as the Gaussian noise (RJ) and limited amount of PJ. This does not include complex ISI or BUJ. With commercially available BERTs, it is impossible to arbitrarily set ISI in particular.

Taking all of these issues into account, software based signal generation avoids these problems and allows flexible parameter configuration. The implemented signal generation starts with a vector of clock timestamps used to determine the points in the signal where the transmitter produces each respective symbol. These may be equidistant, and increasing time samples can be frequency modulated (like SSC). The sequence of timestamps is modified by adding timing (i.e. horizontal) impairments/perturbations, such as periodic sinusoidal signals, unbounded random noise and bounded unknown (OBUJ) horizontal impairments.

The resulting sequence of timestamps is combined with a random bit sequence, and applied to a filter to create a waveform with limited rise/fall times. In the last step, vertical perturbations are added, such as periodic vertical sinusoidal signals, vertical Gaussian noise and bounded vertical BUJ due to vertical impairments from other signal sources.

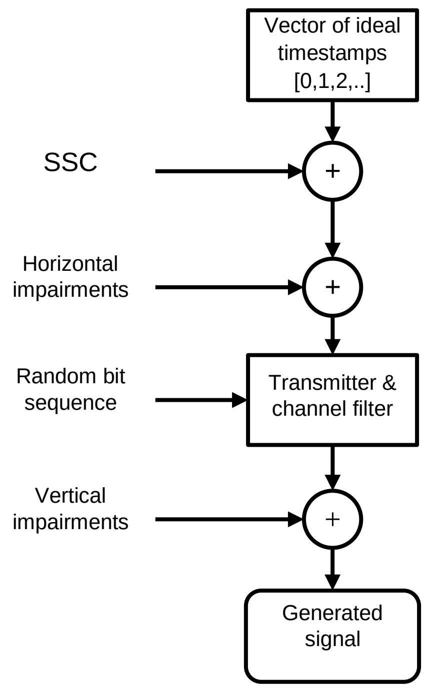


Fig. 3-1: Flowchart of the signal generation environment

In order to generate test signals for the various jitter test cases, signal generation is regulated by varying the above-mentioned parameters. The maximum frequency content of the signal and consequently, the signal model's step response, are altered by applying different filters. This effectively changes ISI and DCD such that varying the cut-off frequency of the filter will impact the DDJ peak-to-peak value. By eliminating the offset (high to low) and asymmetries between the rise/fall times of the step response, it is possible to get rid of the DCD component.

The vertical and horizontal periodic components are varied to generate a signal with periodic jitter. Finally, an input reference signal with the desired amount of random jitter is generated by controlling the unbounded (in amplitude) random vertical impairments and unbounded random horizontal impairments.

In the test signals that are generated for comparing the decomposition algorithms, some amount of DDJ is present for all test cases. This is due to the fact that an oscilloscope's input signal is always band-limited. This is necessary because the oscilloscope performs interpolation for the TIE calculation and this interpolation is inaccurate if the signal is not band-limited.

The signal generation environment produces reference waveforms that are converted into an appropriate file format depending on the oscilloscope vendor. The digital data for every reference waveform is the same. Once loaded, the jitter analysis is performed on these reference waveforms using the corresponding oscilloscope software.

The next chapter examines the various jitter algorithms and analysis frameworks.

4 Analysis framework

This chapter discusses the Rohde & Schwarz jitter and noise analysis framework and compares it to the algorithms used by competitor solutions. The goal is to understand the differences and additions that each vendor provides. Rohde & Schwarz uses a joint jitter and noise analysis framework based on the sampled signal data. Instead of using TIE data, the Rohde & Schwarz approach relies on all waveform samples.

Using the sampled data, the step response includes transmitter and channel effects, all of which result in a data-dependent signal disturbance, i.e. inter symbol interference. A comprehensive explanation of this topic is beyond the scope of this paper. For details on the Rohde & Schwarz joint jitter and noise analysis framework, see [1].

We will now provide a brief summary of the jitter analysis framework of the competitor solutions:

Competing vendors' jitter algorithms base their jitter decomposition on the measured TIE data. This involves sampling of the phase error with a low resolution of 1 UI. Once the parameters are calculated, their total jitter at the specified bit error rate is calculated based on the Dual-Dirac model – a conventional method in commercial jitter estimation solutions. The estimation depends on the measured TIE data. It isolates the statistically independent DJ and RJ components as DJ is bounded in amplitude. The Dual-Dirac model is a simplistic model and has a few shortcomings. The Dual-Dirac model depends on two parameters: DJ ($\delta\delta$) and RJ (σ). DJ ($\delta\delta$) represents the two outermost peaks of the DJ probability density function (PDF).

There is no explicit way to calculate DJ ($\delta\delta$) since the total jitter PDF might not have two dominant peaks. Moreover, estimation of RJ (σ) is a challenge due to its Gaussian nature and the presence of crosstalk. Furthermore, most RJ measurement techniques face issues when crosstalk and other forms of bounded uncorrelated jitter are present. Another issue is that in case RJ does not follow a flat noise floor in the spectrum, then the basis of the model collapses or there is an RJ overestimation if the DJ distribution mimics the RJ distribution. Amplitude noise can also create issues [2]. There is also no exact DJ ($\delta\delta$) measurement. Therefore, competitors have enhanced their jitter analysis algorithms.

In an initial step, DDJ is determined. This is dependent on finding a repeating pattern or a set of patterns with the same length in the signal. If a pattern does not exhibit a transition at the end, the TIE cannot be measured. Note that the new estimated step response approach from Rohde & Schwarz does not rely on any repeating pattern [1]. The TIE data for each pattern is averaged, thus resulting in a vector of DDJ data and the DCD value [3].

The averaged value DDJ vector is subtracted from the original TIE vector in order to remove the data dependent jitter such that only periodic jitter, random jitter and bounded uncorrelated jitter remain. This requires sufficient data for each pattern, but we have less TIE data for averaging as the pattern length increases [3, 4].

In order to perform spectral analysis via a Fourier transform on this new TIE vector, the TIE vector must be equidistant in time. But TIE values are only available if there is a bit transition (like 0b01 or 0b10). In case of a missing transition, the data set is interpolated into a waveform that has one value per unit interval by interpolating TIE values for edges not present in the waveform ("virtual edges"). Given the typical transition density of 50 % in a data stream, there is a high degree of uncertainty.

Spectral analysis of this track is performed using an FFT transformation. Peaks that exceed a threshold are identified as periodic jitter contributors. This works well for pure white noise since the noise floor is flat and a simple threshold is a good approach. In case of a non-uniform noise floor (e.g. in the presence of pink noise), however, this simple threshold method is not sufficient.

Once the above-mentioned periodic jitter contributions are identified and removed from the spectrum, the remaining spectrum consists of random and other bounded uncorrelated jitter (OBUJ). The remaining spectrum is integrated and becomes the sigma value of the Gaussian distributions (Parseval's theorem) to be used in the Dual-Dirac model. In the presence of crosstalk and OBUJ, the noise floor is raised, resulting in an overestimated RJ, which is one major disadvantage of the spectral method.

For this reason, certain vendors have developed modifications for improved RJ estimation. One vendor uses Q scale extrapolation [5] to fit the Gaussian distribution of the Dual-Dirac model. However, the sigma and population for each Gaussian distribution can be different (thus allowing additional degrees of freedom) and they are not determined from the spectral analysis.

Other vendors first formulate the histogram of the jitter series to identify the left and right tails. Then, after normalizing the distributions, they obtain two Gaussian curves with the parameters DJ ($\delta\delta$) and RJ, which fit these tails, respectively [3].

Unlike the traditional decomposition approaches described above, Rohde & Schwarz uses the oscilloscope sampling rate, thus avoiding aliasing of vertical PJ components. Identification of data dependent jitter is based on the step response estimation, which also enables processing of longer non-repetitive patterns. Unlike the TIE based method, no addition of virtual edges is performed via interpolation. The random jitter value is not determined through the spectrum. Instead of estimating TJ@BER, it is calculated based on the step response estimation and the RJ and PJ analysis. The next chapter introduces the test cases that are used for comparison purposes.

5 Jitter test cases

In order to compare the decomposed jitter values of the different jitter decomposition tools, various test cases were defined. This helps to distinguish how the decomposition algorithms work for different jitter components. All jitter solutions analyzed the same test cases based on a common signal loaded as a reference waveform.

All features that are not common to all of the vendors were ignored in order to focus on comparability. This applies to OBUJ separation, vertical PJ and noise. Vertical periodic components were not introduced into the input signal because except for Rohde & Schwarz, most vendors identify the vertical periodic components as RJ due to their pure TIE based analysis approach.

For all of the oscilloscopes, the objective was to apply the same settings. The CDR settings were configured for a 2nd order PLL with a loop bandwidth of 10 MHz, a damping factor of 0.7 and a bit rate of 5 Gbps. The sampling rate was set to 20 GSps and the symbol rate to 5 Gbps.

The record length (RL) could not be kept the same for the comparison because the software CDRs in the different solutions exhibited different locking behaviors. Depending on the vendor, the RL varied between 4 MSa and 10 MSa.

One vendor had a sampling rate of 25 GSps that could not be lowered to 20 GSps. In this case, all timing values were scaled accordingly in order to obtain directly comparable results.

All reference levels for the TIE measurements were set to values of 10 % – 50 % – 90 % (low / mid / high) for the analysis. All values are recorded in mUI (milli unit interval) where a unit interval (UI) corresponds to one bit period. The pattern length for the DDJ detection was set to 10.

5.1 Combined jitter (TC4)

The first test case contained a signal with a combination of all three types of jitter (RJ, PJ, DDJ) taking into consideration all necessary conditions for comparability across the vendors. This allows comparison of the accuracy of the jitter algorithms.

Fig. 5-1 shows the TIE histograms for the signal across all vendors. The graph is normalized so that the vertical and horizontal scaling is the same. Since the TIE is the starting point for the jitter decomposition, it is shown that all of the oscilloscopes identify a similar TIE vector from the input signal. The number of events is different because of the different record length and locking behavior of the CDR.

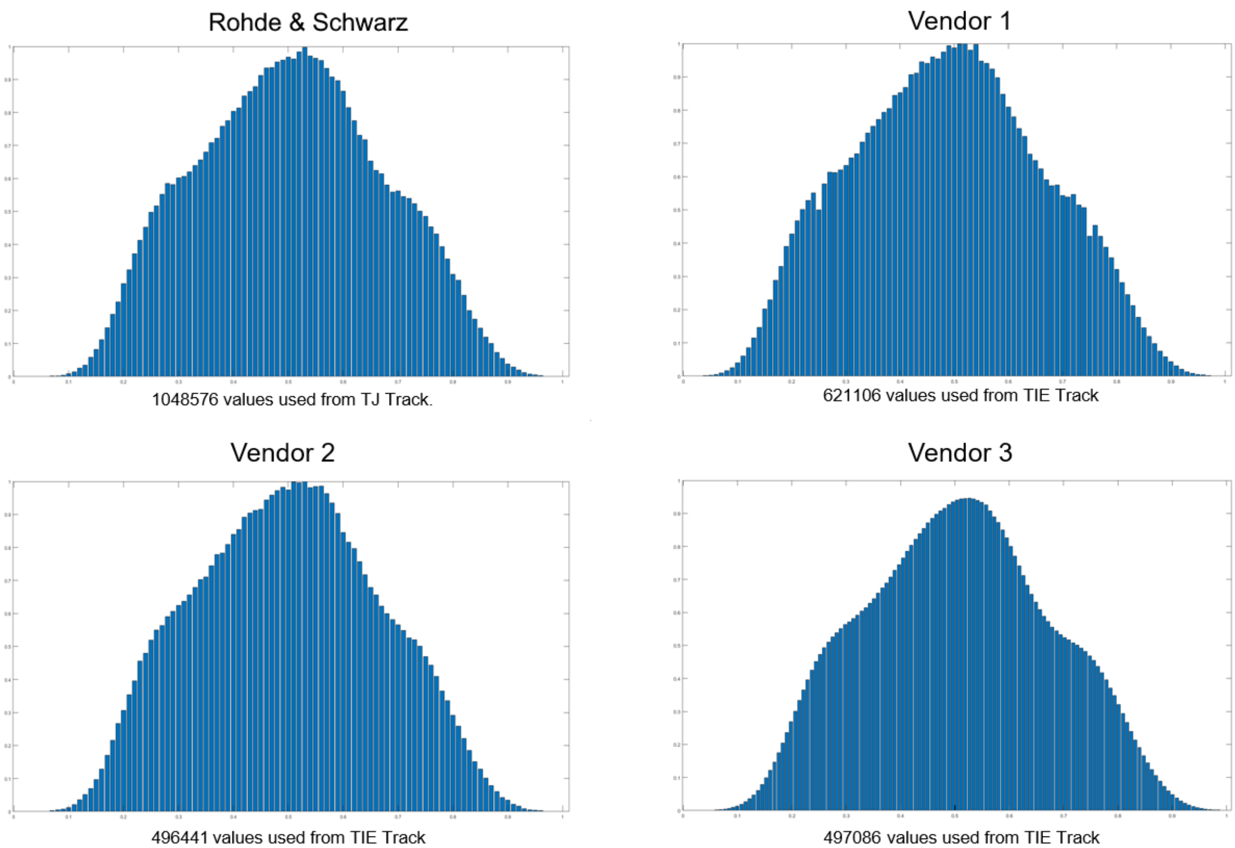


Fig. 5-1: Comparison of the total jitter using histograms

After performing jitter analysis on the given test signals, once in the absence of SSC and once in the presence of SSC, the following results are obtained:

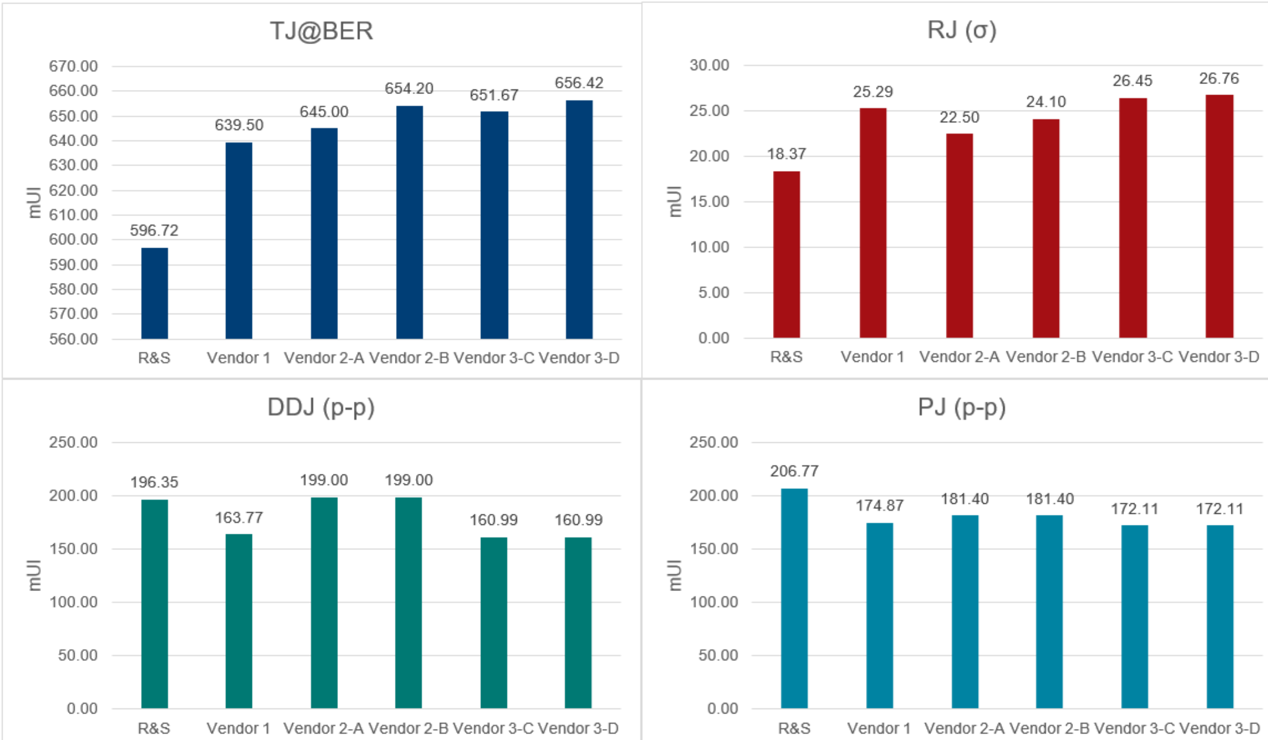


Fig. 5-2: Combined jitter without SSC

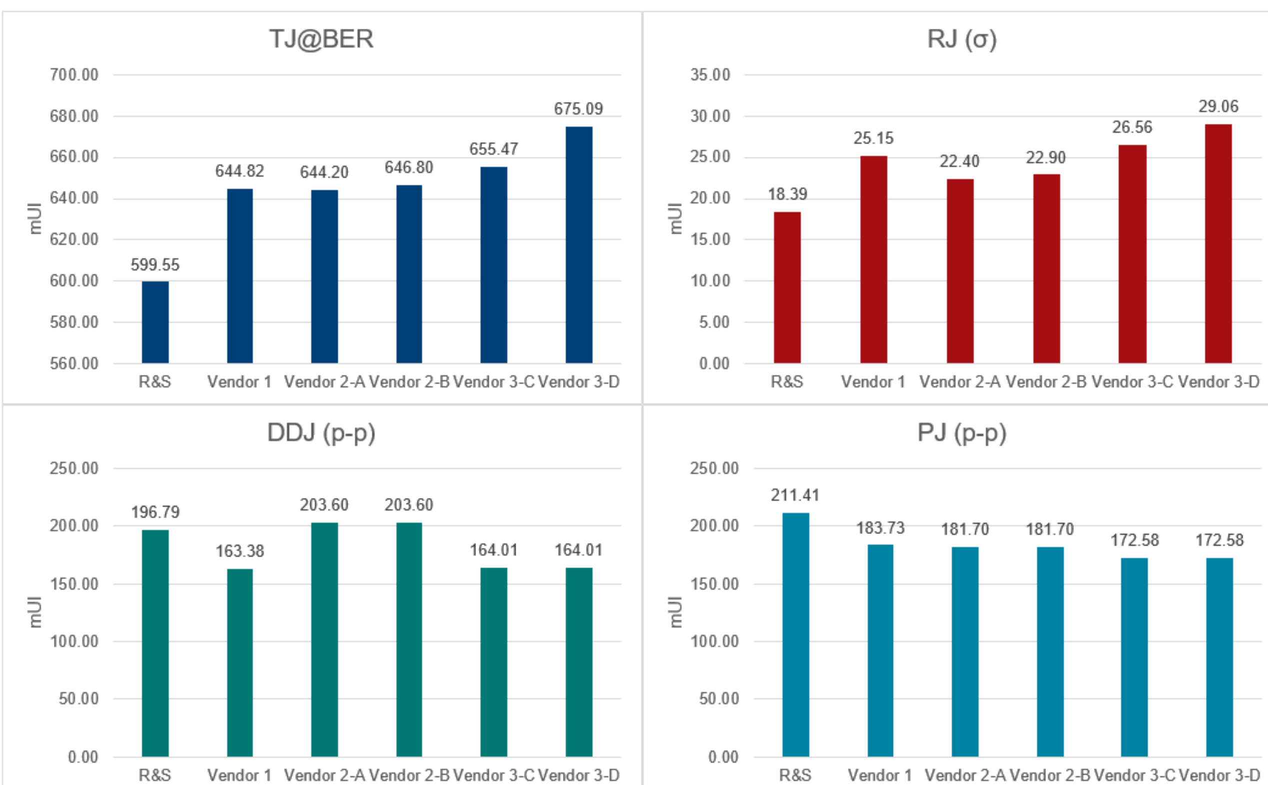


Fig. 5-3: Combined jitter with SSC

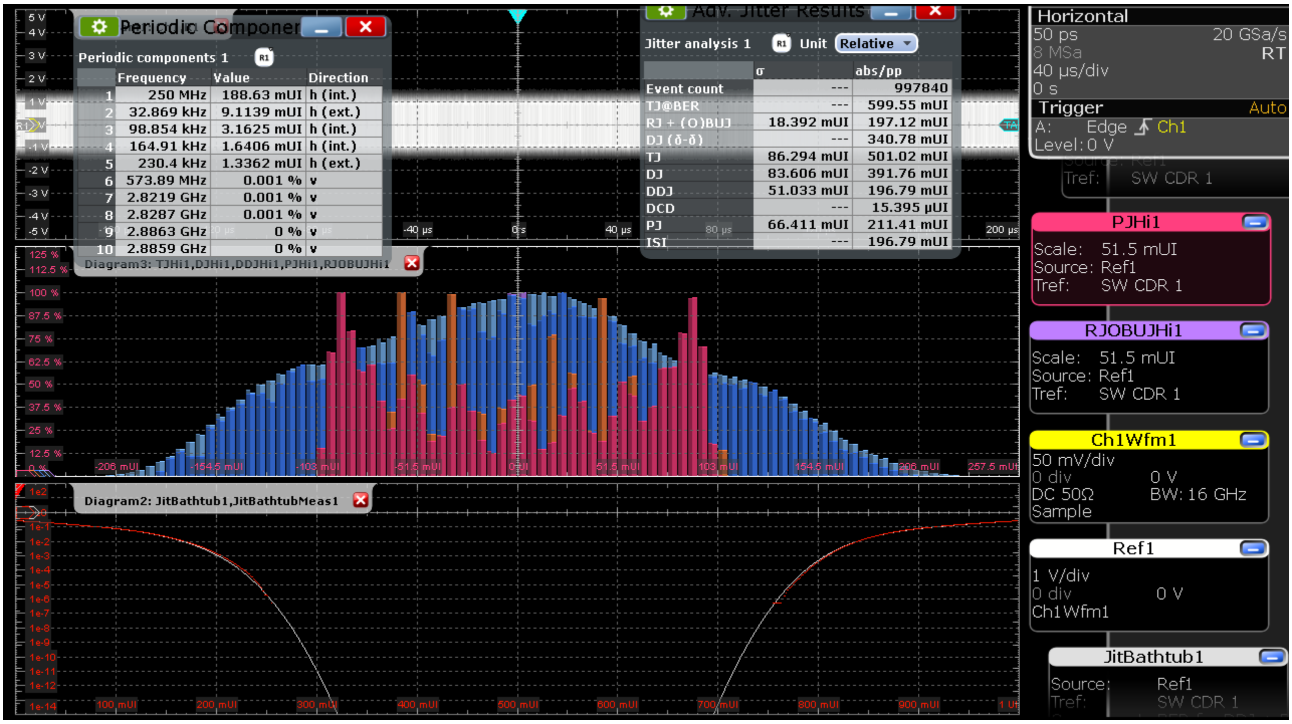


Fig. 5-4: Screenshot of the R&S®RTP oscilloscope with combined jitter with SSC waveform

The obtained results are displayed in Fig. 5-2 and Fig. 5-3 as a bar chart for comparison. The results are labeled with Rohde & Schwarz or Vendor 1-3. If a vendor offers additional extensions for the algorithms (see chapter 4), the results were labeled with -A, -B, -C, -D. A few points that stand out are:

- Rohde & Schwarz has the lowest TJ@BER and RJ (σ) value compared to others.
- The DDJ (p-p) value for Rohde & Schwarz and Vendor 3 are close and comparable and those for Vendor 2 and Vendor 4 are lower.
- Rohde & Schwarz and Vendor 1 have a noticeable difference in the PJ (p-p) value when SSC is introduced into the reference input signal.

Here, it is challenging to interpret the test result and find a suitable explanation for the differences in this signal. It is not possible to exactly trace the input parameters to the difference in the results. For example, a large RJ value at the n^{th} UI position cannot be identified if there is no data transition. The configured parameters (RJ, PJ, DDJ) are not traceable and will not be exactly reflected in the results of the test case.

In order to understand whether the parameters (RJ, PJ, DDJ) are recognized by the algorithms, we need test cases that allow the individual jitter components to be assessed along with an observation of how they are recognized together. Therefore, the following test cases were added:

- Test case 1 (TC1): Reference waveform with 200 mUI p-p of data dependent jitter with SSC
- Test case 2 (TC2): Reference waveform with 200 mUI p-p of 250 MHz periodic jitter with and without SSC
- Test case 3 (TC3): Reference waveform with RJ (sigma) of 18 mUI with SSC
- The RMS value is considered for RJ because it is Gaussian in nature and for the provided record length, it is equivalent to 200 mUI of p-p.

5.2 Data dependent jitter (TC1)

This input signal for the DDJ test case identifies the data dependent jitter detection across the scopes. A reference input signal with 200 mUI of DDJ is generated and the same pattern length is set for DDJ identification across all of the oscilloscopes. DCD is removed by eliminating the asymmetries in the rise/fall times of the signal and choosing the threshold appropriately.

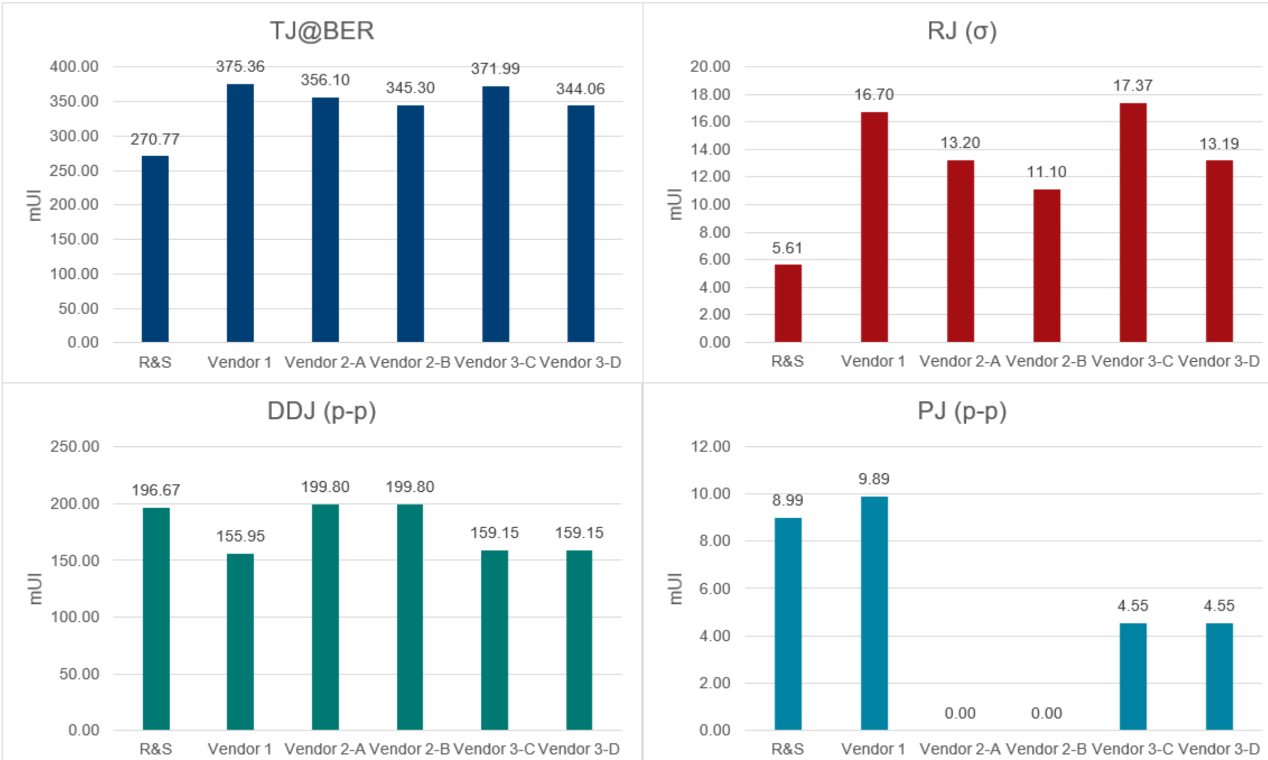


Fig. 5-5: Data dependent jitter

The DDJ (p-p) values for Rohde & Schwarz and Vendor 2 are close to 200 mUI. Vendor 1 and Vendor 3 have lower values. Compared to Rohde & Schwarz, other vendors show higher RJ (σ) contributions in this test case. The PJ (p-p) contributions are low across all vendors, relative to the injected 200 mUI of DDJ jitter.

5.3 Periodic jitter (TC2)

This input signal for the PJ test case identifies the periodic jitter across the scopes. Here, two scenarios are considered. One input signal contains triangular SSC modulation and the other input signal does not. This makes it possible to see the impact on the jitter values after introduction of SSC. A reference input signal with around 200 mUI of peak-to-peak PJ is given.

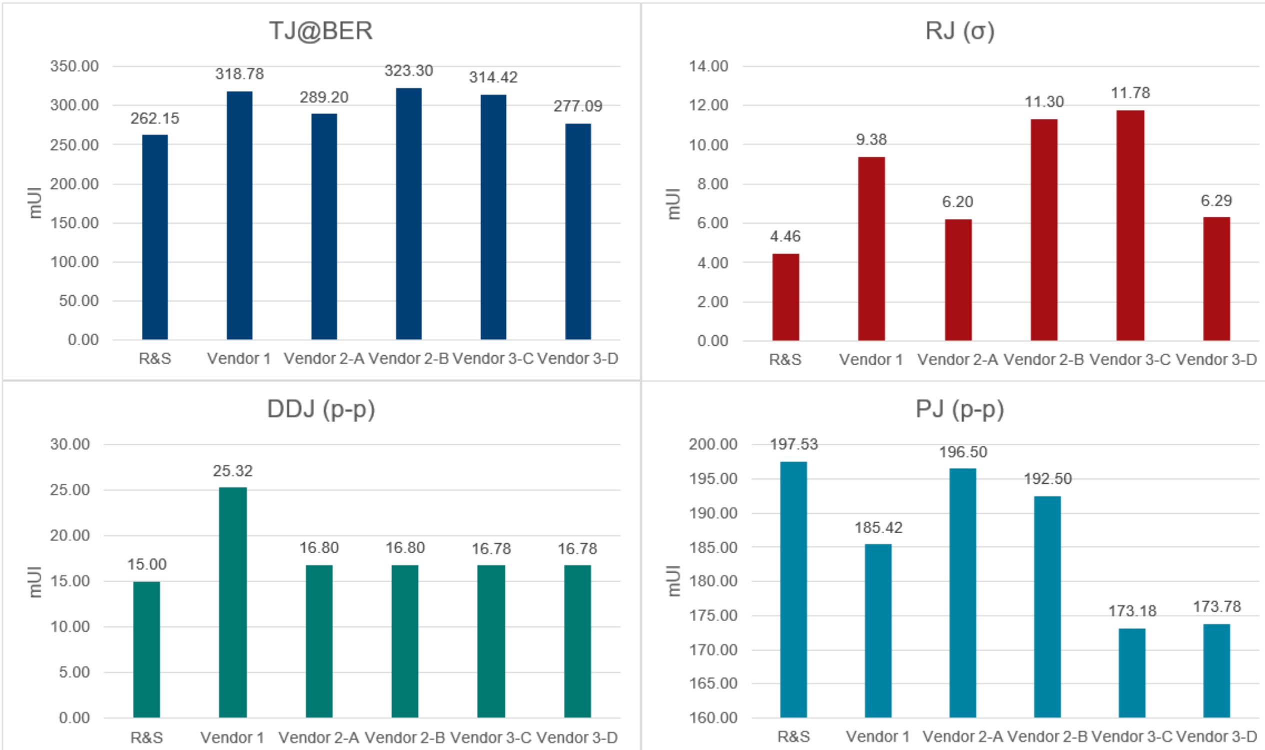


Fig. 5-6: Periodic jitter without SSC

The PJ (p-p) values for Rohde & Schwarz and Vendor 2 are close to 200 mUI. Vendor 1 and Vendor 3 have lower values. For the competition, the PJ values are based on the peaks that are observed in the signal spectrum after elimination of DDJ. Therefore, if all of the peaks are not detected, it is highly likely that some are reflected in RJ instead. In contrast, Rohde & Schwarz derives PJ components as part of the signal model parameter fit. Both periodic vertical and horizontal components are estimated in terms of amplitude, frequency and phase.

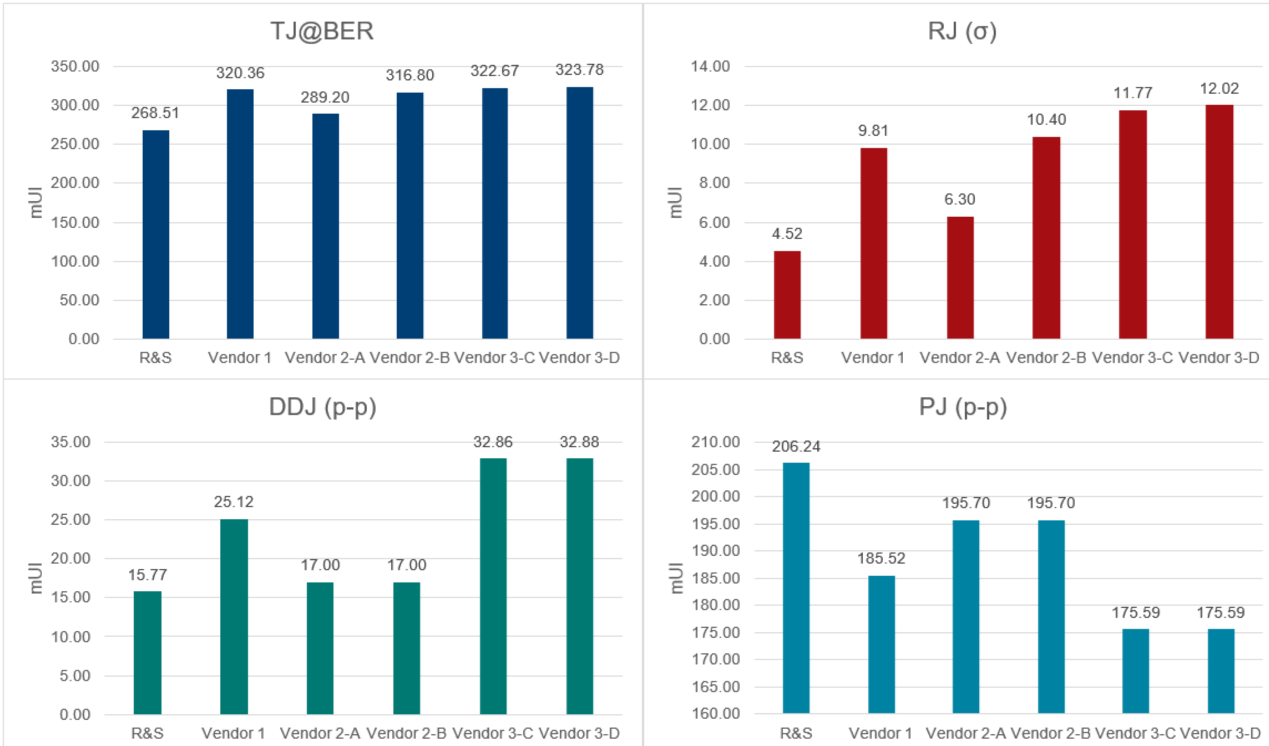


Fig. 5-7: Periodic jitter with SSC

Frequency	Value
250 MHz	191.28 mUI
32.883 kHz	8.9667 mUI
98.576 kHz	3.0904 mUI
164.93 kHz	1.6784 mUI
230.44 kHz	1.4354 mUI

Table 5-1: Periodic components in the presence of SSC

Table 5-1 shows the periodic jitter contributors at various frequencies detected by the Rohde & Schwarz algorithm. The SSC modulation frequency of 33 kHz and the odd harmonics are identified and listed. The increase from 197.53 mUI to 206.24 mUI in the Rohde & Schwarz PJ value due to SSC modulation is evident and roughly corresponds to the sum of the SSC fundamental and all harmonics.

Other vendors show small changes in the PJ value, but for Vendor 3, there is a sudden rise in the DDJ (p-p) value from 16 mUI to 32 mUI and a sudden rise in RJ (σ) from 6 mUI to 12 mUI for Vendor 3's method D. It seems as if the change in SSC is misinterpreted and has ended up in DDJ and RJ.

5.4 Random jitter (TC3)

This input signal is provided to help understand the identification and comparison of random jitter across the oscilloscopes. It produces about 18 mUI of RJ (σ).

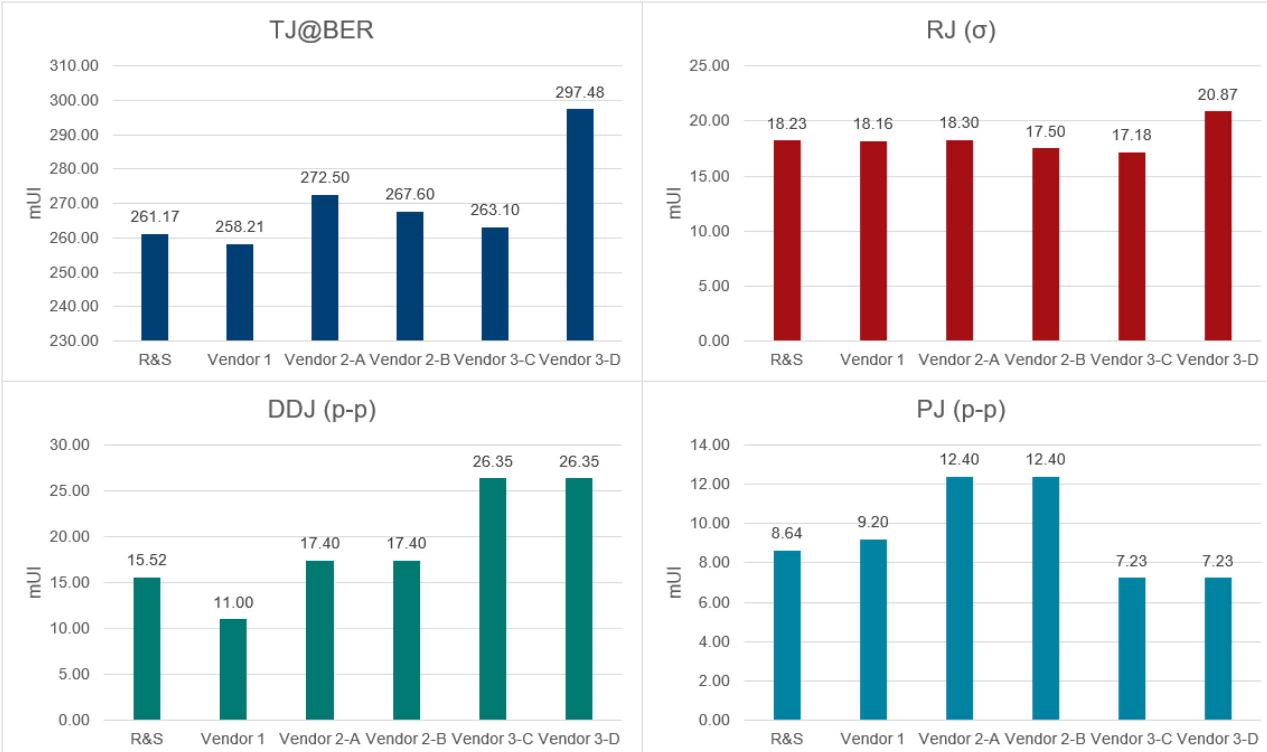


Fig. 5-8: Random jitter

The identified RJ (σ) is in a similar range across the scopes. Method D of Vendor 3 records a slightly higher value. The DDJ values are low, but Vendor 3 has a noticeably higher DDJ (p-p) value. The PJ (p-p) value is the highest for Vendor 2.

5.5 Conclusion on combined jitter (TC4)

Analyzing the individual jitter components in the separate test cases, it is clear that the values are reasonably comparable across vendors and are within limits in the same range.

Going back to the very first reference input signal analyzed at the beginning of this chapter, it consists of a combination of all test cases 1-3 with the same amount of jitter contribution as is present in the individual test cases. Comparison of the results now becomes easier once all types of jitter components have been analyzed separately and then added together in one signal as shown.

The following observations were made from Figure 4:

► The RJ (σ) value for Rohde & Schwarz is the lowest. The competitors' jitter decomposition algorithms show higher RJ (σ) values which contribute to significantly higher TJ@BER.

► Rohde & Schwarz and Vendor 2 record a higher value of DDJ (p-p) close to 200 mUI compared to Vendor 1 and Vendor 3.

► For PJ (p-p), we see that Rohde & Schwarz attains a high value in the range of 200 mUI while other oscilloscopes record a lower value.

After adding SSC, the following observations were made from Fig. 5-3:

► For RJ (σ), Rohde & Schwarz is still the lowest with a similar value. Other scopes record higher values with slight fluctuations, e.g. a slight decrease in the Vendor 2 value with method B and an increase in the Vendor 3 method D value.

- ► Rohde & Schwarz and Vendor 2 record a higher value of DDJ (p-p) compared to Vendor 1 and Vendor 3. There is a slight increase in the DDJ value of Vendor 2.
- ► Due to the presence of SSC, a noticeable change is observed in the PJ values of Rohde & Schwarz and Vendor 1. There is a slight increase that is reflected in TJ@BER as well.

In conclusion, it is clear that when a reference input signal with a combination of all jitter components is used as the input, the RJ (σ) value recorded by other vendors is slightly higher. The DDJ identification of Vendor 1 and Vendor 3 is low. A rise in the jitter values is observed when SSC is added. But overall, the jitter values from these four test signals are comparable across all four scopes, thus proving our main argument.

Looking at the individual jitter cases and then coming back to the combined jitter case, we can clearly see how much each individual jitter value contributes when all of the signals are mixed together. The next chapter will compare how well the separation works in the vendor-specific solutions.

6 Comparing the individual jitter components per vendor

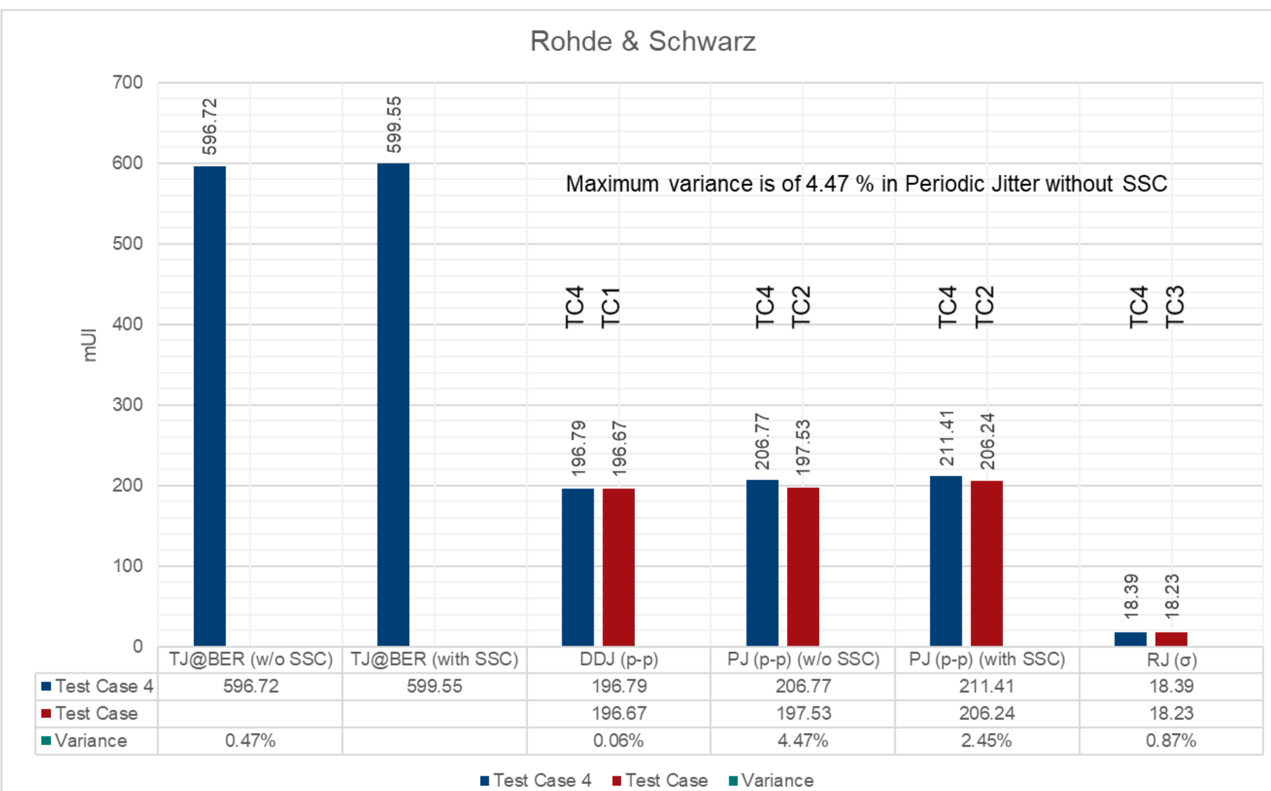
This chapter focuses on detection of the individual jitter components by the various vendor solutions.

To understand the decomposition and consistency of the results, DDJ (p-p) from TC1 is compared with the DDJ (p-p) value from TC4, PJ (p-p) from TC2 is compared with the PJ (p-p) value from TC4, and RJ (σ) from TC3 is compared with the RJ (σ) value from TC4. Since the jitter components are the same in test cases TC1-3 and TC4, the expectation is that they should be very close. In order to calculate the variance between test cases with the individual jitter component and the combined test case, the individual test case is used as a reference.

The following figures should help to illustrate this comparison.

In order to understand whether any particular value is overestimated in the algorithms, the next chapter compares the individual test cases with the combined jitter signal test case for each and every jitter type and for each individual oscilloscope.

6.1 Rohde & Schwarz

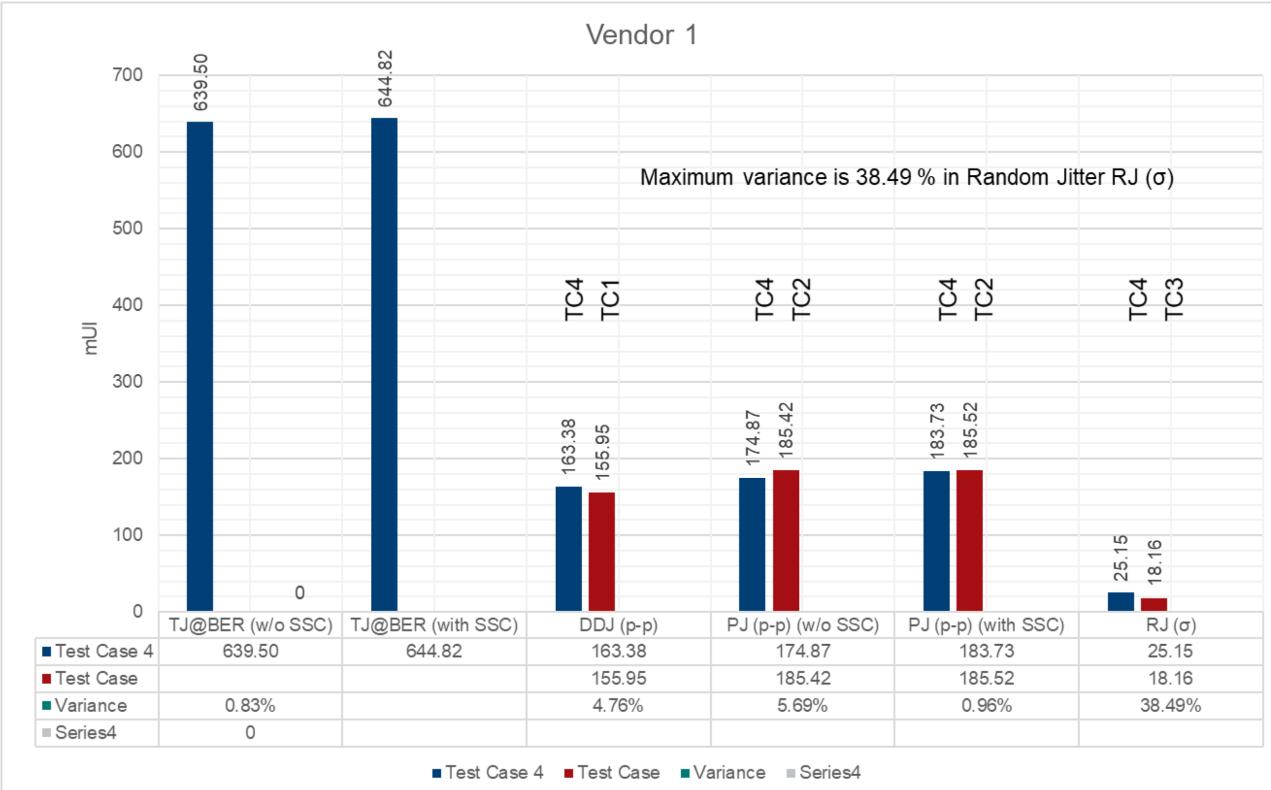


	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	596.72	599.55	196.79	206.77	211.41	18.39
Test Case			196.67	197.53	206.24	18.23
Variance	0.47%		0.06%	4.47%	2.45%	0.87%

Fig. 6-1: Vendor-specific comparison for Rohde & Schwarz

Only for PJ is a slightly higher percentage of the PJ value observed when SSC is present in the input signals. The other jitter component values do not vary for the test cases with just an individual jitter component or the test case with combined jitter components.

6.2 Vendor 1

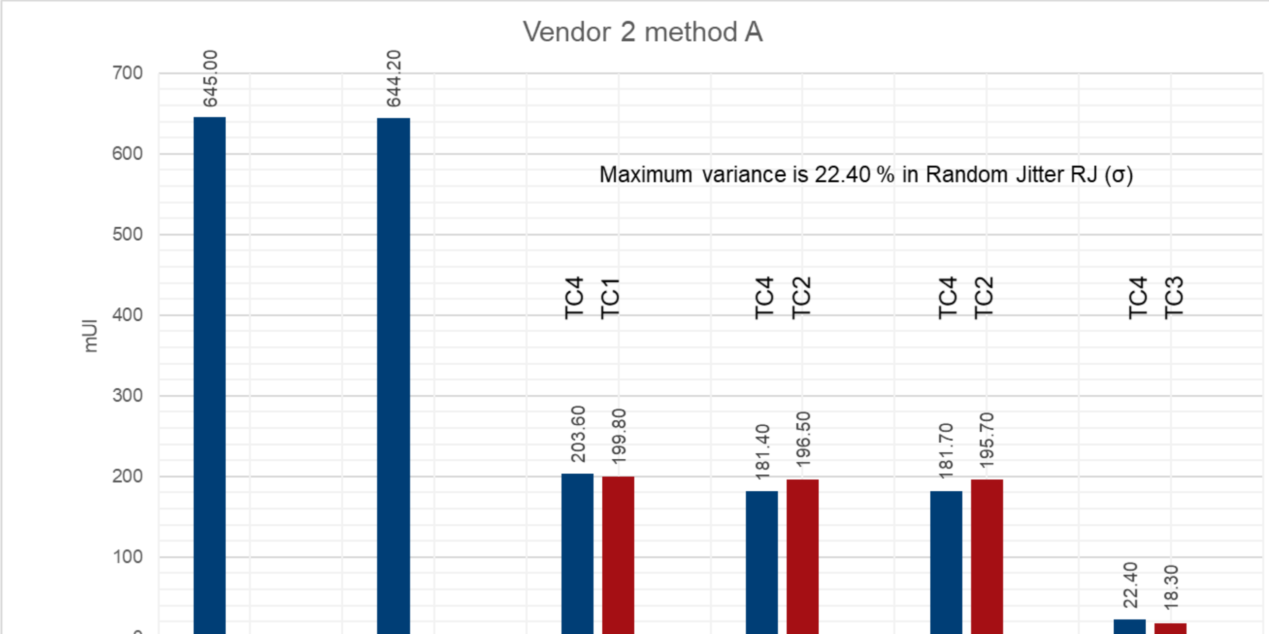


	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	639.50	644.82	163.38	174.87	183.73	25.15
Test Case			155.95	185.42	185.52	18.16
Variance	0.83%		4.76%	5.69%	0.96%	38.49%
Series4	0					

Fig. 6-2: Vendor-specific comparison for Vendor 1

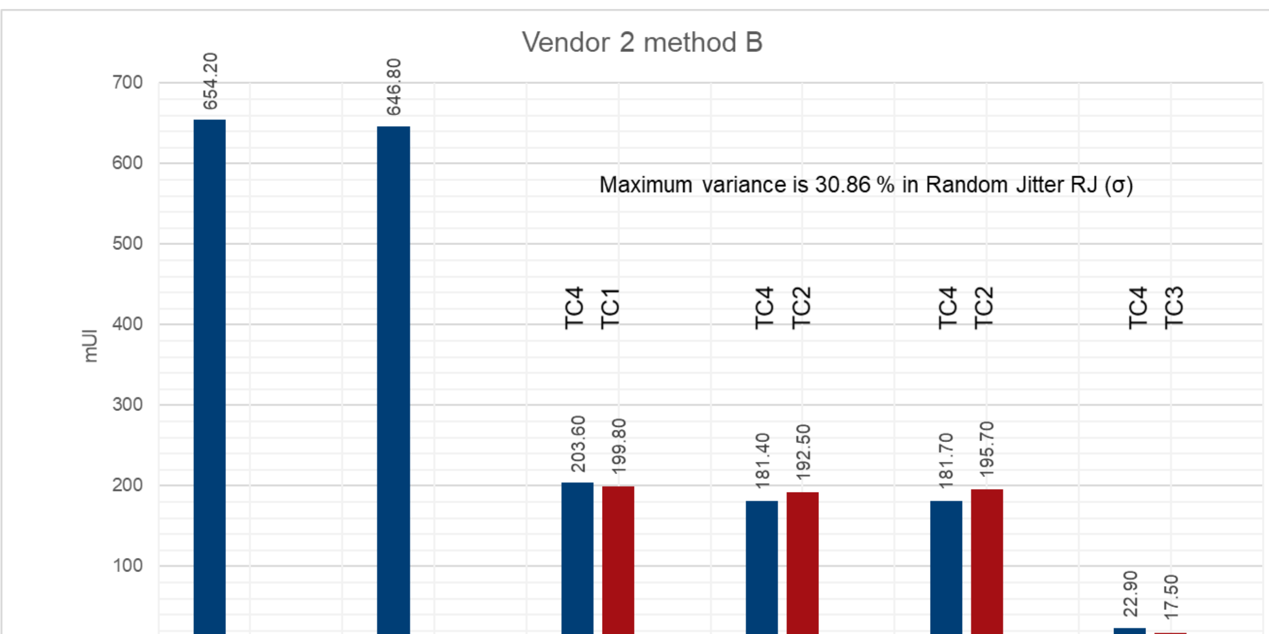
The RJ (σ) value varies the most. DDJ and PJ also vary, but not as much as RJ (σ).

6.3 Vendor 2



	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	645.00	644.20	203.60	181.40	181.70	22.40
Test Case			199.80	196.50	195.70	18.30
Variance	0.12%		1.90%	7.68%	7.15%	22.40%

Fig. 6-3: Vendor-specific comparison for Vendor 2 method A

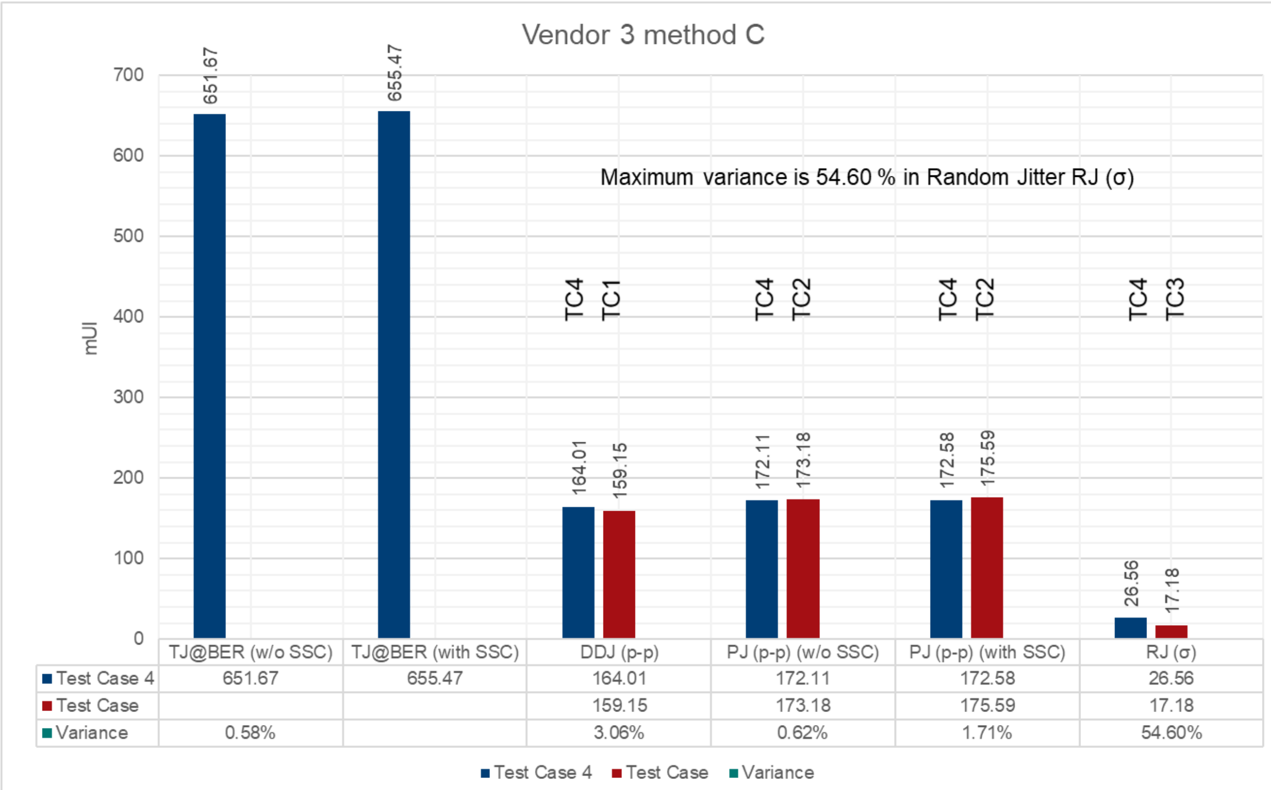


	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	654.20	646.80	203.60	181.40	181.70	22.90
Test Case			199.80	192.50	195.70	17.50
Variance	1.14%		1.90%	5.77%	7.15%	30.86%

Fig. 6-4: Vendor-specific comparison for Vendor 2 method B

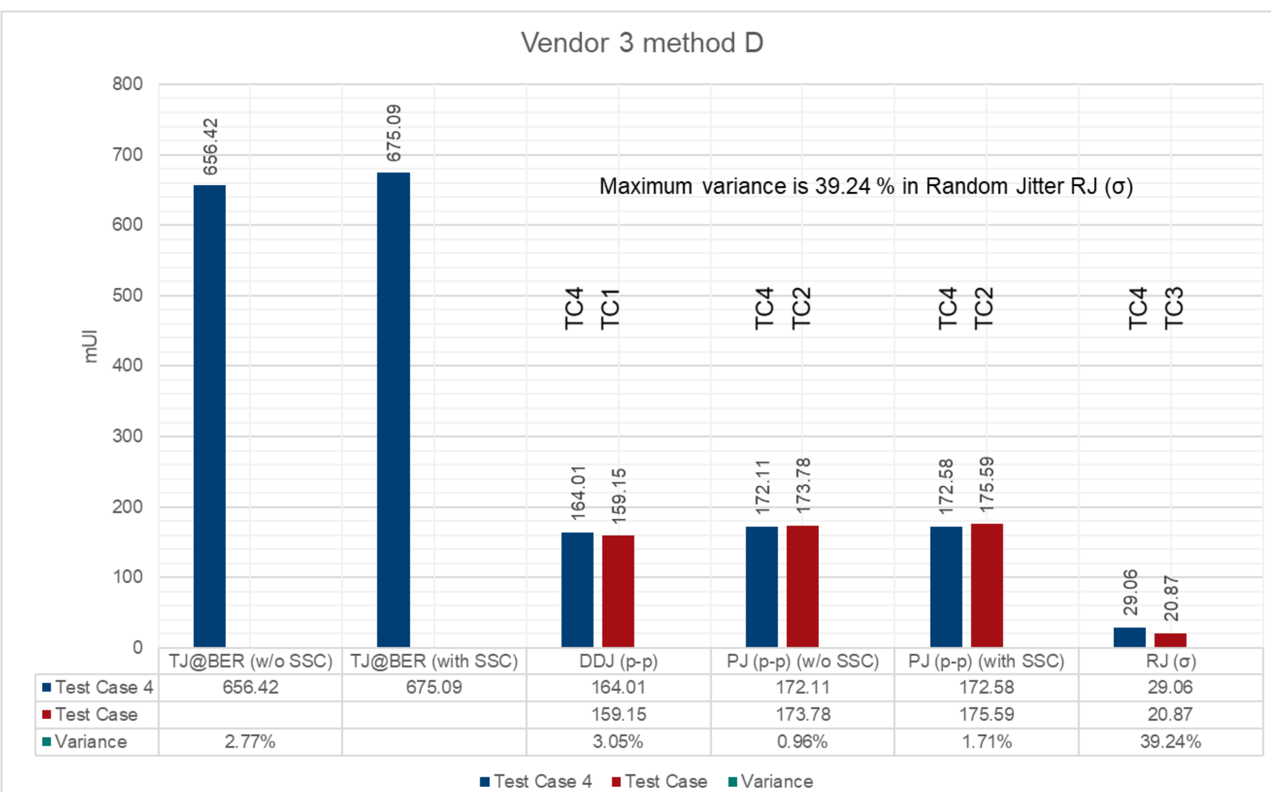
Method B of Vendor 2 seems to exhibit more variance in its RJ (σ) value compared to method A. However, it is supposed to yield better results for RJ decomposition because this method avoids deriving RJ (σ) from the common noise floor. The other jitter values do not exhibit particularly high variance.

6.4 Vendor 3



	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	651.67	655.47	164.01	172.11	172.58	26.56
Test Case			159.15	173.18	175.59	17.18
Variance	0.58%		3.06%	0.62%	1.71%	54.60%

Fig. 6-5: Vendor-specific comparison for Vendor 3 method C



	TJ@BER (w/o SSC)	TJ@BER (with SSC)	DDJ (p-p)	PJ (p-p) (w/o SSC)	PJ (p-p) (with SSC)	RJ (σ)
Test Case 4	656.42	675.09	164.01	172.11	172.58	29.06
Test Case			159.15	173.78	175.59	20.87
Variance	2.77%		3.05%	0.96%	1.71%	39.24%

Fig. 6-6: Vendor-specific comparison for Vendor 3 method D

Method C of Vendor 3 seems to exhibit more variance in its RJ (σ) value compared to method D. The other jitter values do not vary significantly.

6.5 Conclusion

The above comparison reveals that Vendors 1, 2 and 3 estimate higher RJ values when all of the jitter signals are combined into one. In contrast, Rohde & Schwarz obtains relatively consistent values. All other jitter values do not vary significantly across all four oscilloscopes.

7 Summary

This paper has compared the joint jitter and noise analysis framework of Rohde & Schwarz vs. other oscilloscope based, commercially available jitter analysis frameworks. A software signal generation environment was used to individually configure the jitter contributions and to output vendor-specific reference waveforms. All of the individual vendor-specific frameworks could read these waveforms, ensuring identical signal conditions for all jitter decomposition solutions. Four different test cases were used to analyze the decomposition.

After comparing the Rohde & Schwarz framework with that of the other oscilloscopes, Chapter 5 showed just how close and comparable the jitter results are for test cases in which only one jitter component is applied. However, a difference is noticed in the results when spread spectrum clock (SSC) jitter is added to the reference waveforms. Rohde & Schwarz is best in identifying the difference in the periodic jitter value. Chapter 6 reveals that the competing oscilloscope vendors consistently produce higher RJ values when all of the jitter signals are combined together - a common perception in the market. This analysis has clearly demonstrated that the Rohde & Schwarz algorithm is both dependable and stable.

8 Literature

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[4] R. Stephens, "Measuring ISI at high data rates is impossible," 06 2012. [Online]. Available: https://www.edn.com/measuring-isi-at-high-data-rates-is-impossible/.

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9 Ordering Information

Designation	Type	Order No.
16 GHz RTP oscilloscope	R&S®RTP164	1320.5007.16
Jitter analysis option	R&S®RT-K133	1800.6860.02
Jitter & noise analysis option	R&S®RT-K134	1800.6977.02

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1 SL | Version 0e | 12.2021
Application Note | Comparison of commercial solutions
Data without tolerance limits is not binding | Subject to change