SIGNAL INTEGRITY ANALYSIS FOR HIGH SPEED DATACOM INTERFACES

Analyzing high speed datacom interfaces is an important task and ensures signal integrity. One major challenge of this analysis is the connection between the physical interface and the oscilloscope, as most of the datacom interfaces do not provide test connections suitable for RF. A test fixture is required as a bridge between the high speed datacom IF and the RF connector of the oscilloscope, but this will affect the signal integrity measurement. The R&S®RTP and R&S®RTO2000 oscilloscopes with the advanced jitter option can analyze and separate jitter contributions. Additionally, the option can evaluate the impact of test fixtures and traces inherently and give the user a good understanding of the impact of their test setup.

Your task

You have to characterize a high speed datacom interface such as PCIe, USB, SATA or HDMI™. Signal integrity is an important part of this characterization, and one challenge is to connect the DUT properly to the test and measurement equipment. This could be an oscilloscope, a spectrum analyzer or a vector network analyzer.

Typically, these interfaces are designed for consumer products and have low-cost commercial connectors with undefined RF characteristics, unlike e.g. an SMA connector. A test fixture is required as a bridge between the interfaces and the test and measurement equipment, but these test fixtures influence the measurement, which cannot be neglected. Deembedding techniques would be an option, but the characterization of these fixtures is a challenge.

Rohde & Schwarz solution

The R&S®RTP and R&S®RTO2000 oscilloscopes are capable of in-depth signal integrity analysis. The jitter analysis provides a breakdown of the key parameters. All parameters, except the bit error rate (BER), can be viewed in the time domain as a track, in the frequency domain as a spectrum and statistically as a histogram.

Additionally, the R&S®RTP-K133/RTO-K133 advanced jitter option introduces two new features that extend the analysis beyond these well-known jitter parameters:

- Synthetic eye diagram: lets the user explore the effect of certain jitter parameters on the data eye
- Intrinsic measurement of the step response of the transmission channel: comprises the data dependent characteristics of the DUT, the test fixture and cabling

The step response is important, because it covers the influence of the test fixture on the signal integrity analysis. The user can perform various measurements based on the step response to understand the influence of the test fixture on the analysis.

Application

As an example, this application card describes analyzing a differential signal (8.125 Gbps, PRBS31) generated by a bit error rate test (BERT) with spread spectrum clocking (SSC) and no jitter additions. The signal is propagated via a long trace over a PCIe Gen4 ISI board (PCIe-VAR-ISI). The intersymbol interference (ISI), introduced by the board, was the dominating contribution to the jitter. This particular setup allows the verification of the step response using a vector network analyzer (VNA), which is shown at the end.

Application Card | Version 01.00

It is important to analyze the jitter in the same way, just as the receiver would receive and clock the data. The oscilloscope therefore captures the differential TX data and uses a hardware clock data recovery (CDR) to trigger on the data signal (see Fig. 1). Notice the high update rate (122 000 waveforms/s) of the R&S®RTP high-performance oscilloscope.

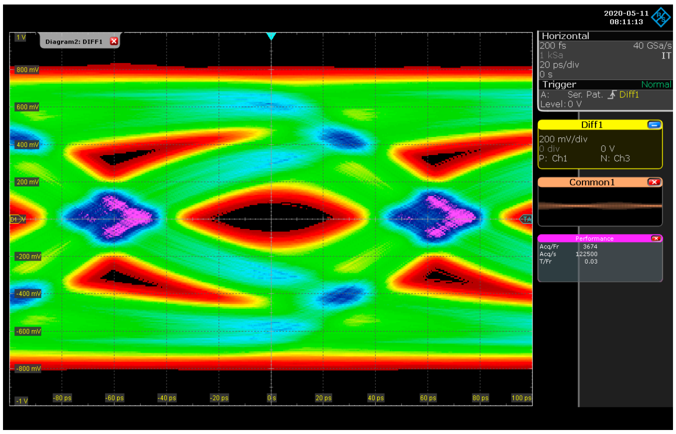


Fig. 1: Differential eye pattern of a PRBS31 with large ISI.

Prior to the analysis, the acquisition time should be set to a value that considers the minimum frequency resolution required for the periodic jitter analysis. To accomplish a resolution down to 40 kHz, which is in the range of switched-mode power supplies (SMPS), and a sampling rate of 40 Gsample/s, the record length is set to 2 Msample (= 2 × (sample rate)/(SMPS switching frequency)) and consequently the acquisition time to 50 µs.

The jitter decomposition algorithm analyses the differential channel as a non-return-to-zero (NRZ) signal. The necessary CDR is configured with a second order phase-locked loop (PLL) with a bandwidth of 16 MHz.

The jitter decomposition in Fig. 2 shows results in a table and the statistical data as histograms (TJ, RJ, PJ, DDJ [1)]), which as expected is dominated by the DDJ. The bathtub curve of the BER illustrates a good accordance between the measured and the calculated BER. The novel part in this decomposition is the estimated step response shown in the middle of Fig. 2. The step response is the result of an ideal step applied to the transfer function of the channel. An uncalibrated test fixture would be inherently part of this estimation.

[1)] TJ: total jitter, RJ: random jitter, PJ: periodic jitter, DDJ: data dependent jitter.

The user has the option to configure the step response length in the estimation; in this case, it is set to 75 UI. Setting the step response length is governed by three principals:

- The longer the configured step response length, the longer the computation time.
- The step response length should be longer than the channel memory. A long step response is beneficial for detailed step response analysis.
- The run length of the pattern should be longer than the step response length.

The user can analyze the step response with familiar tools such as a cursor and automated measurements. In the example, the rise time is measured via a cursor. The measurement of the rise time t_r lets the user estimate the bandwidth f_B of the channel, using the approximation $f_B = 0.35/t_r$, which is valid for a single-pole lowpass filter.

More detailed analysis in the frequency domain is therefore of interest. Topics such as overshoot, droop and ringing of the transfer function are also visible in the frequency domain.

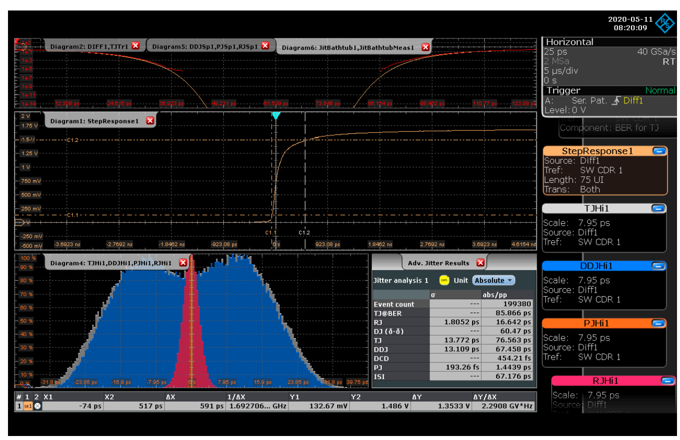


Fig. 2: Results for the TJ and RJ spectrum, including a list of periodic components, TJ/RJ/PJ/DDJ histograms and the measured and calculated bathtub.

In addition to the histograms and the estimated step response, Fig. 3 shows the associated transfer function of the step response in the frequency domain in magnitude (see marker M1) and phase (see marker M2). To calculate the transfer function in the frequency domain based on a step response, the math menu offers a set of functions [1]:

- Step2FreqRespNormMag(<channel>,<points>)
- Step2FreqRespNormPhi(<channel>,<points>,<delay>)

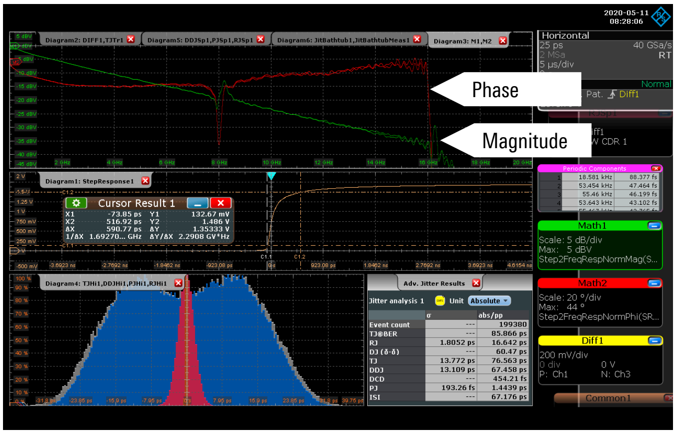


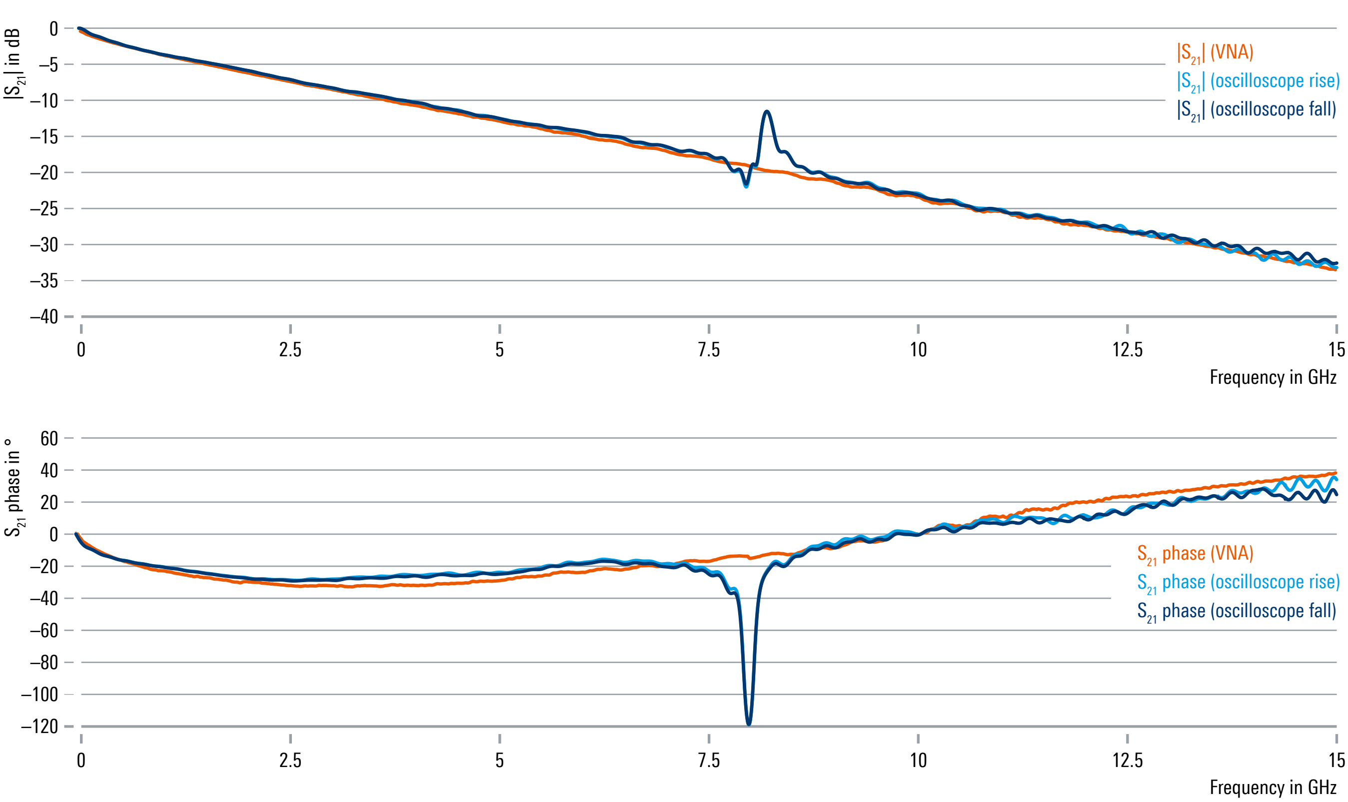
Fig. 3: Step response of the DUT plus test fixture and the transforms for magnitude and phase.

As expected, the magnitude shows a frequency dependent attenuation, mainly caused by dielectric losses. The skin effect is rather small. The phase shows the dispersion of the trace. For both traces, every value above 16 GHz is noise because of the limited channel bandwidth. At 8.125 GHz, there is an artifact caused by the data rate.

This measurement was compared with a VNA measurement. As the PCIe Gen4 ISI board introduces the ISI, the associated trace was measured (differential) and the transfer function and the scattering parameter differential/differential (S_{21} DD) compared in the frequency domain (see Fig. 4).

Both measurements show a good accordance in the band of 0 Hz to 16 GHz. The magnitude deviates less than 1 dB and the phase less than 5°.

Fig. 4: Comparison of S_{21} measured by the VNA and the oscilloscope's transfer function estimate.



Summary

The R&S®RTP and R&S®RTO2000 oscilloscopes analyze digital high speed signals for signal integrity. The oscilloscopes measure precisely well-known jitter components such as TJ, RJ, PJ and DDJ. The oscilloscopes also analyze inherently the transfer function, which causes the DDJ. A separate characterization of individual components of the transmission path is challenging due to accessibility, and the output impedance of the signal driver over frequency is typically unknown. Therefore, the inherent measurement of the transfer function is a key element to understand the sources of the DDJ.

References

[1] A. M. Nicolson, "Forming the fast Fourier transform of a step response in time-domain metrology," Electronic Letters, Volume 9, Issue 14, p. 317, 1973.

See also

www.rohde-schwarz.com/product/sw_rtx-k133

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