WAVECREST Corporation

# Comparison of Oscilloscope Performance

## Application Note No. 144

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U.S. Patent Nos. 4,908,784 and 6,185,509, 6,194,925, 6,298,315 B1, 6,356,850 6,393,088, 6,449,570 and R.O.C. Invention Patent No. 146548; other United States and foreign patents pending.

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# Contents

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## Introduction

Signal integrity measurements require instrumentation that accurately reproduces the waveform. One metric, analog bandwidth, is commonly used to determine if the test instrument is appropriate for the application. This paper will show that there are other parameters that influence instrument measurement capabilities. Four, 6GHz analog bandwidth scopes are compared against a 20GHz analog bandwidth equivalent time scope.

## Setup

An Agilent 12GHz pattern generator was used for generating the data signals that were then analyzed by the Agilent 54855A, Tektronix 6604, Wavecrest SIA-3000 and the Agilent 86100. Eye diagram and waveform analysis were performed on each of these oscilloscopes at 2.125Gb/s and 4.25Gb/s using a K28.5 pattern.

## Measurement Results

<u>TEST 1: Serial data at 2.125Gb/s with K28.5 pattern directly from the pattern generator.</u>

In this test we show the performance of each instrument in preserving the signal waveform by measuring an eye diagram and viewing the waveform. A 2.125Gb/s K28.5 data stream with <20ps rise and fall times is used. This first set of plots shows the resulting eye diagrams with a 20GHz sampling scope (Figure 1), a 6GHz sampling scope (SIA-3000 A45 channels) in Figure 2, followed by the three 20Gs/s 6GHz Real Time scopes.

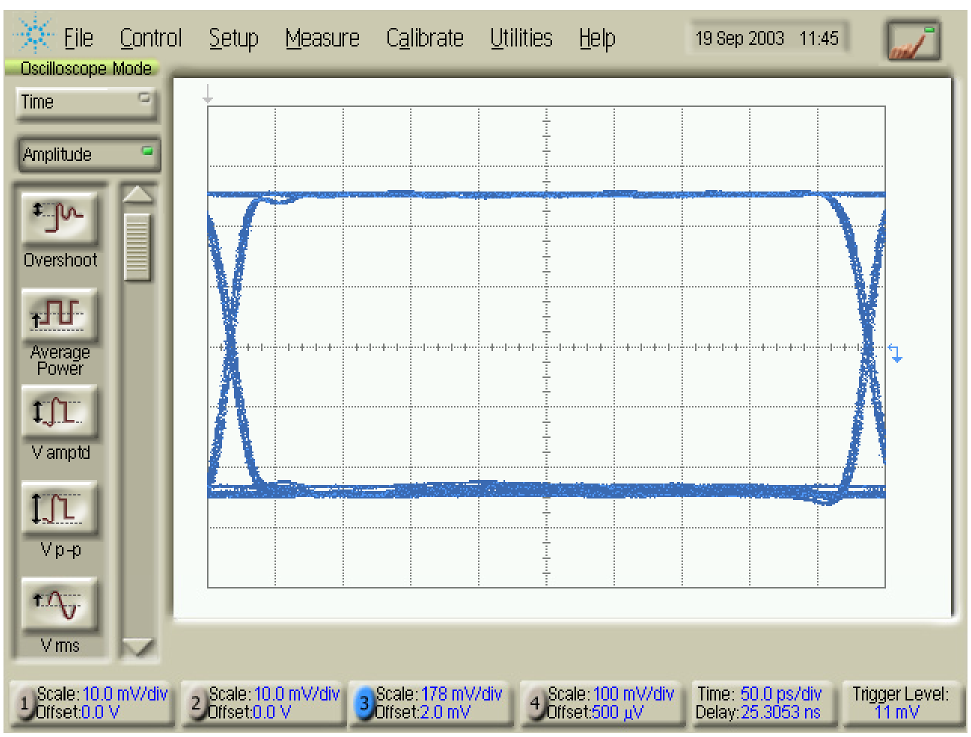


Figure 1 - Agilent 20GHz Sampling scope Eye Diagram of 2.125Gb/s K28.5 pattern.

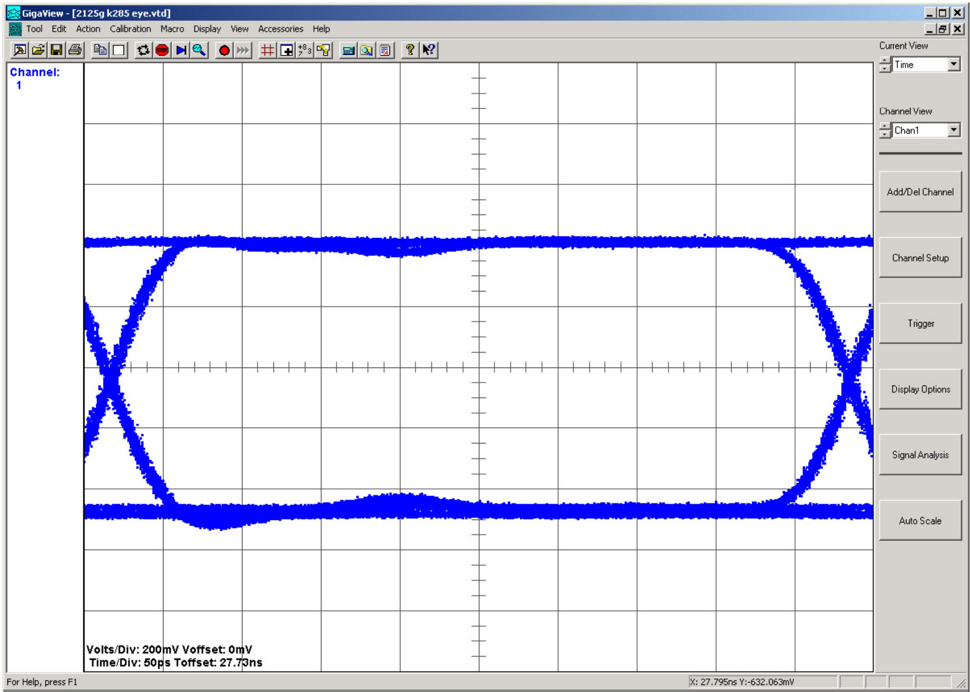


Figure 2 - SIA-3000 6GHz scope Eye Diagram of 2.125Gb/s K28.5 pattern.

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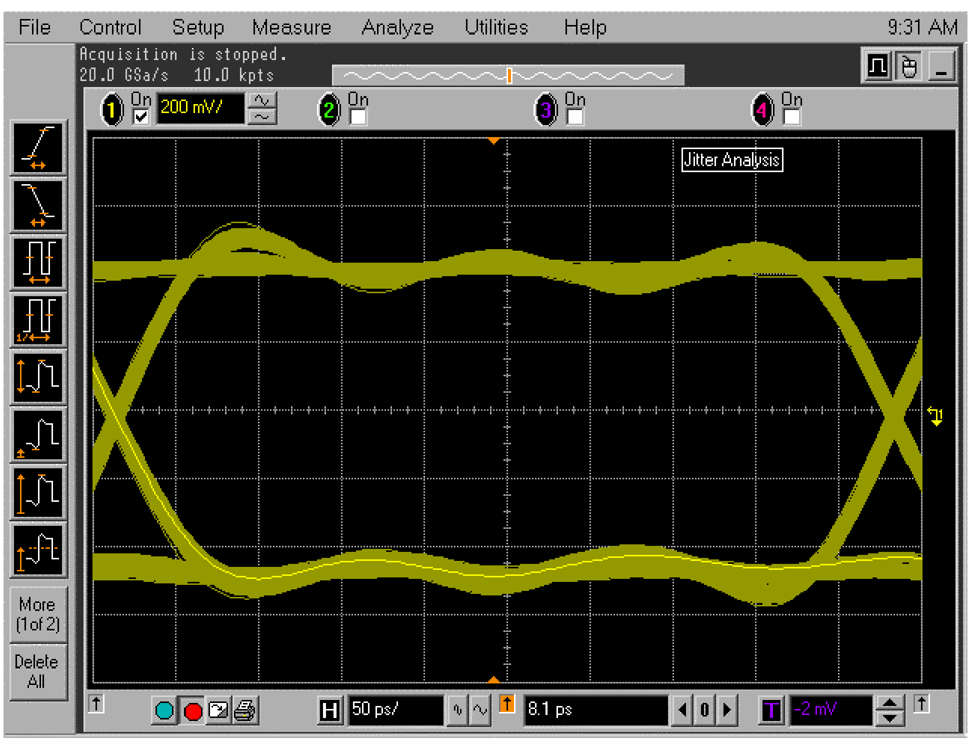


Figure 3 - Agilent 6GHz Real Time Scope Eye Diagram of 2.125Gb/s K28.5 pattern.

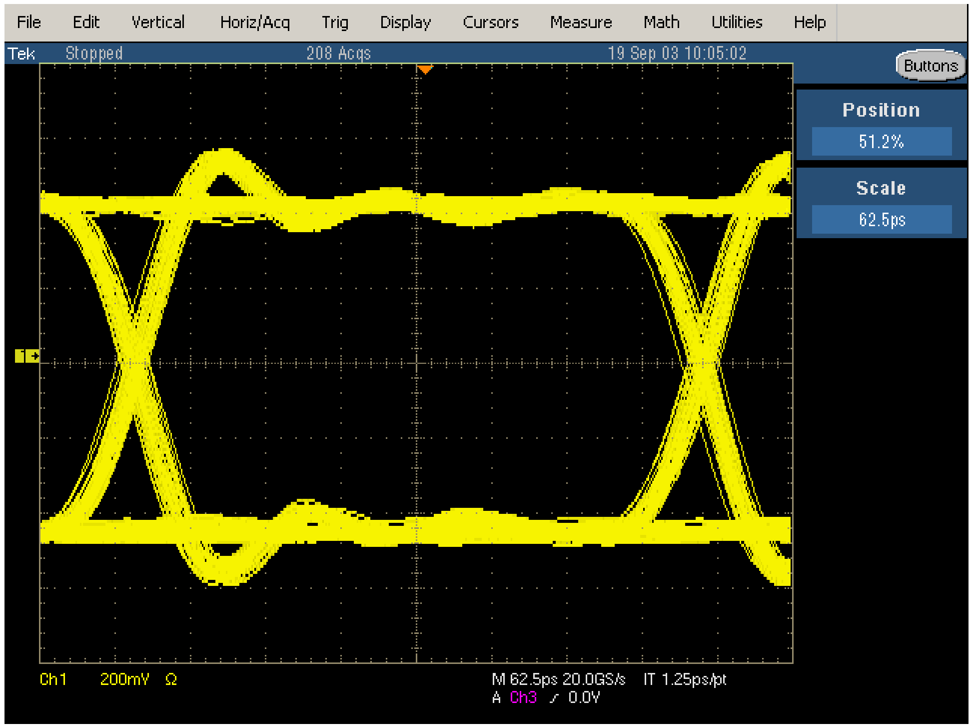


Figure 4 - Tek 6 GHz Real Time scope Eye Diagram of 2.125Gb/s K28.5 pattern.

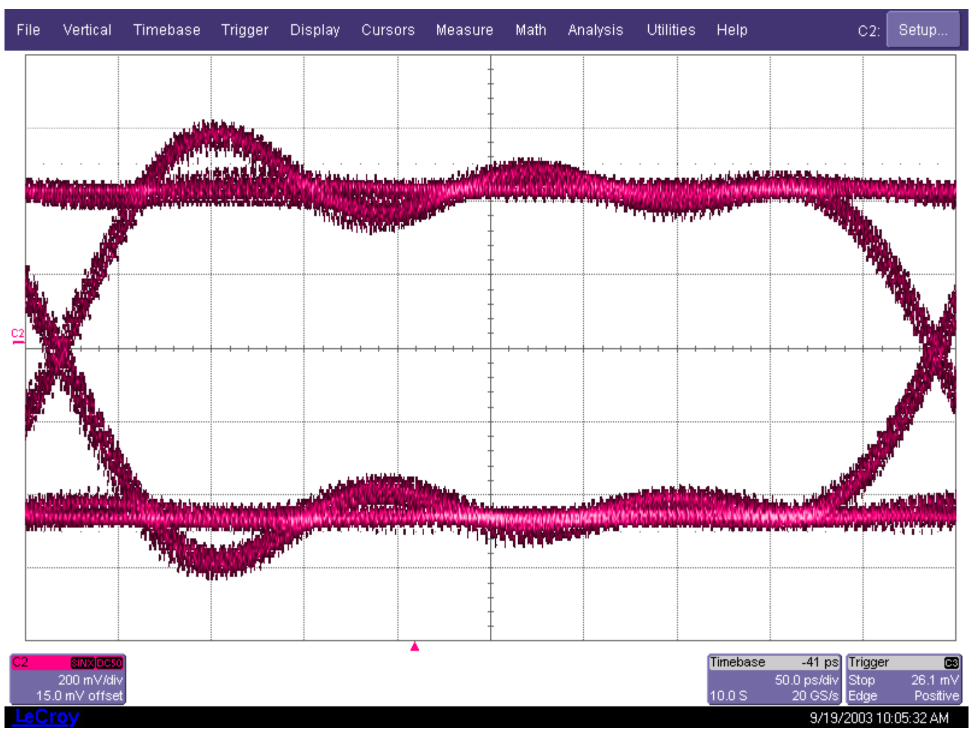


Figure 5 - Lecroy 6GHz Real Time scope Eye Diagram of 2.125Gb/s K28.5 pattern.

Figure 1 shows the best representation of the true shape of the waveform. As you can see in Figure 2 through 5, the 6GHz oscilloscopes do not reproduce the waveform equally. For example, the Real Time oscilloscopes have more ringing after a rising or falling edge compared to the Wavecrest SIA-3000.

Figures 6 through 10 show the pattern used to generate these eye diagrams.

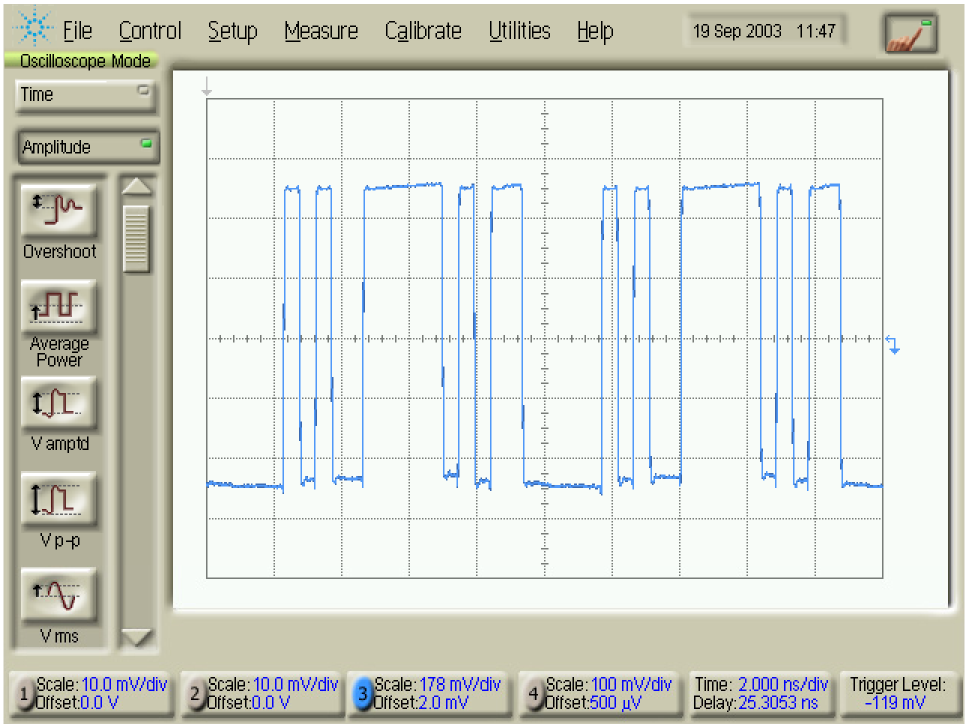


Figure 6 - Agilent 20GHz sampling scope waveform capture of 2.125Gb/s K28.5 pattern.

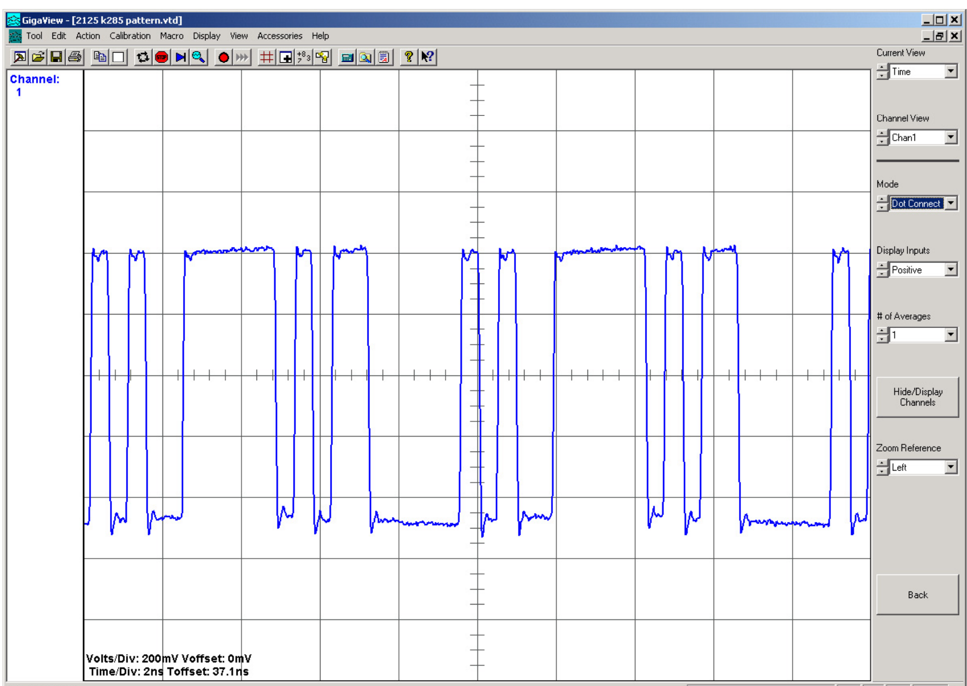


Figure 7 - Wavecrest 6GHz sampling scope waveform capture of 2.125Gb/s K28.5 pattern.

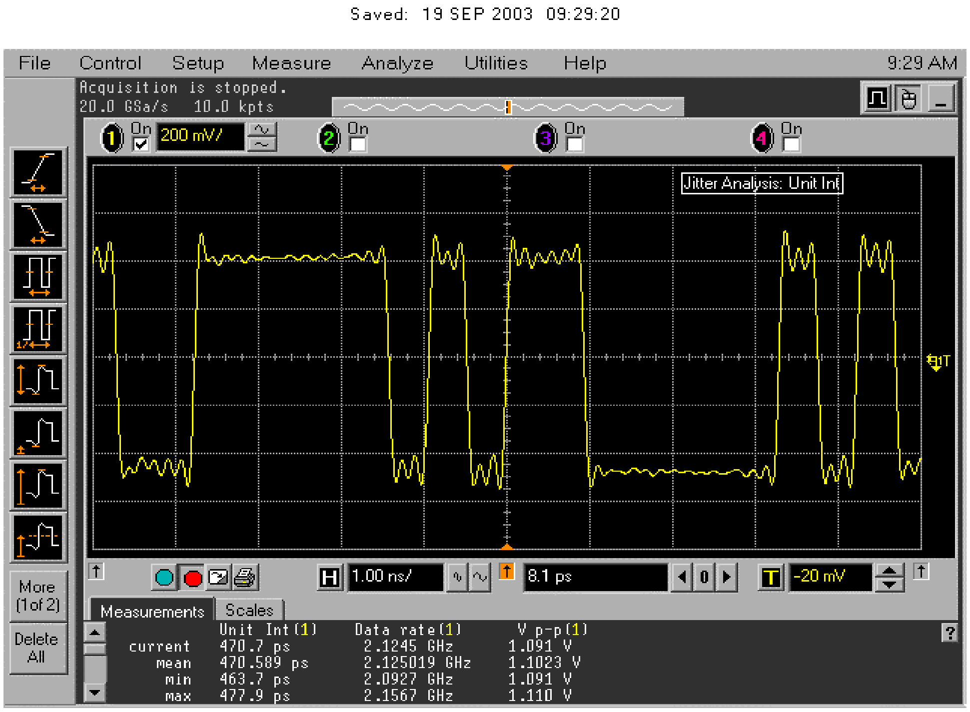


Figure 8 - Agilent Real Time scope waveform capture of 2.125Gb/s K28.5 pattern.


Figure 9 - Tektronix Real Time scope waveform capture of 2.125Gb/s K28.5 pattern.


Figure 10 - Lecroy Real Time scope waveform capture of 2.125Gb/s K28.5 pattern.

Figures 6 through 10 show the variation in waveform reproduction for the four different oscilloscopes. All three Real Time oscilloscopes have excessive ringing before and after edges, which is an indication of poor step response.

This is due to the Real Time scopes all having 50ps resolution. To try and overcome this weakness, they use sin(x)/x or sinc interpolation which accurately reproduces sine waves but not square waves. Today's serial data signals more closely represent square waves, therefore it is important to characterize a signal that represents your device when evaluating oscilloscope performance.

Figure 11 shows all five eye diagrams overlaid in order to compare each instrument's ability to preserve the waveforms shape. The Dark Blue is the Agilent 20GHz sampling scope, the light blue is the Wavecrest SIA-3000 6GHz sampling scope, the Dark Yellow is the Agilent 6Ghz Real Time scope, the Light Yellow is the Tektronix 6GHz Real Time scope, and the Red is the Lecroy 6GHz Real Time scope.

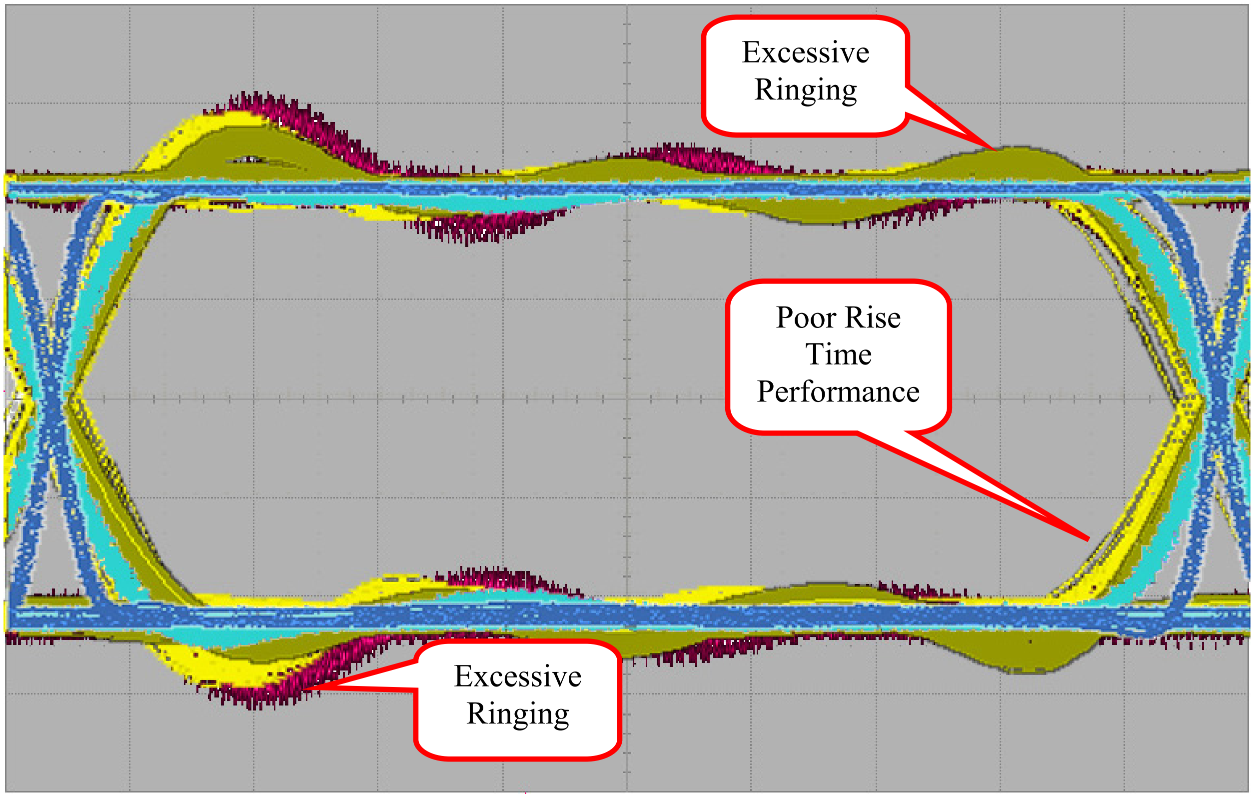


Figure 11 - Overlay of eye diagrams for Agilent 20GHz sampling scope (Dark Blue), 6GHz SIA-3000 scope (Light Blue), Agilent 6GHz (Dark Yellow), Tektronix 6604 (Light Yellow) and the Lecroy 6GHz Real Time scope (Red).

Figure 11 shows the bandwidth limitations (rise/fall time) as well as the poor impulse response (ringing) of the real-time scopes. This shows how inaccurately reproducing the waveform can add error to an eye diagram measurement as well as many other signal integrity measurements on high-speed data signals.

## TEST 2: Serial data at 4.25Gb/s with K28.5 pattern directly from the pattern generator.

In this test we show the performance of each instrument in preserving the signal waveform and producing an eye diagram on a 4.25Gb/s data K28.5 data stream with <20ps rise and fall times. This first set of plots shows the resulting eye diagrams with a 20GHz sampling scope (Figure 12), a 6GHz sampling scope (SIA-3000 A45 channels) Figure 13, an Agilent 6GHz Real Time scope (Figure 14), a Tektronix 6GHz Real Time scope (Figure 15) and the Lecroy 6GHz Real Time scope (Figure 16).

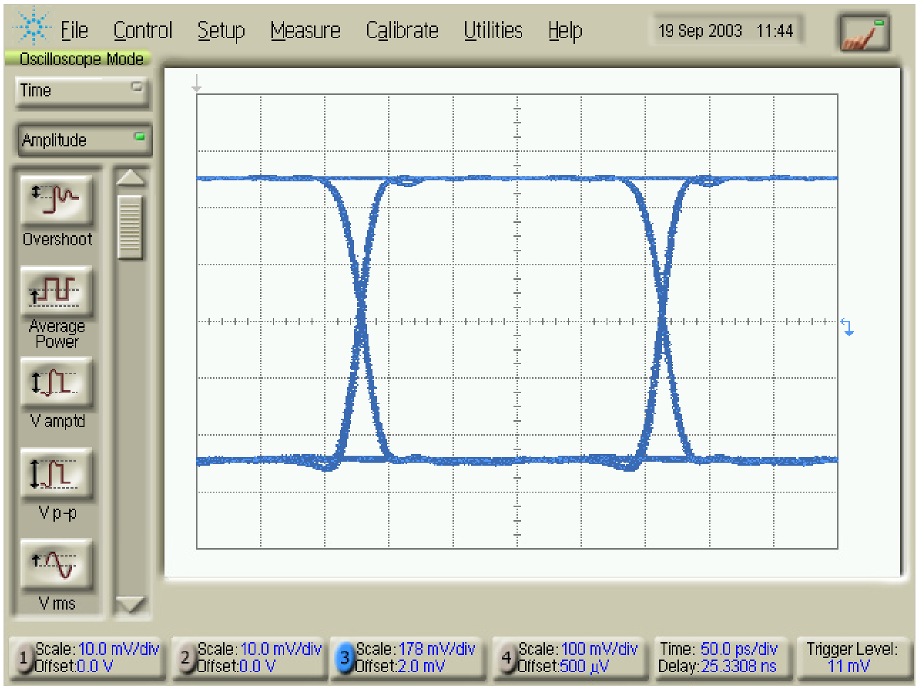


Figure 12 - Agilent 20GHz sampling scope waveform capture of 4.25Gb/s K28.5 pattern.

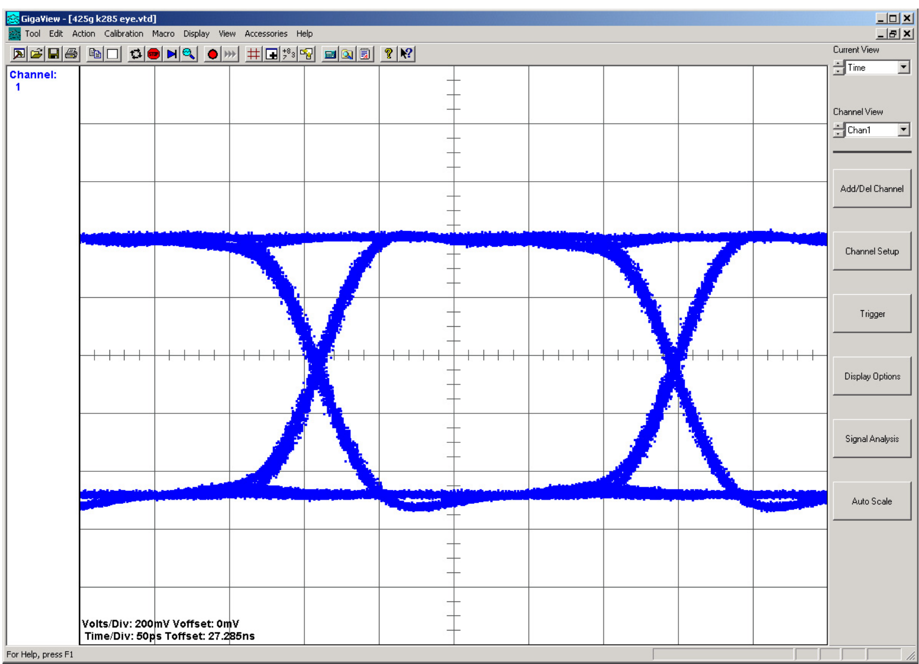


Figure 13 - Wavecrest's 6GHz sampling scope waveform capture of 4.25Gb/s K28.5 pattern.

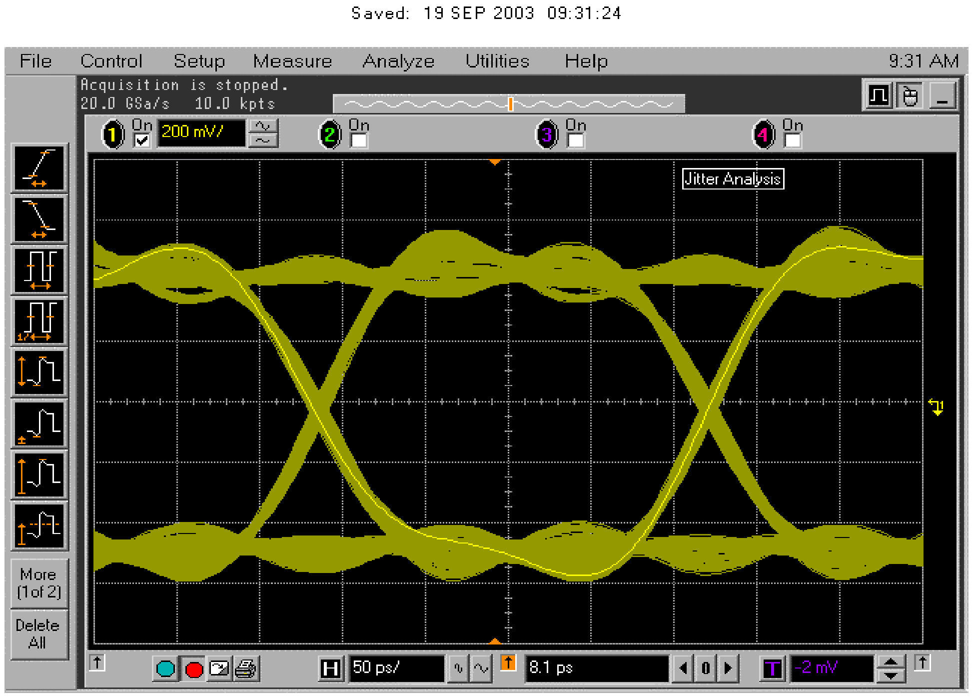


Figure 14 - Agilent 6GHz Real Time scope waveform capture of 4.25Gb/s K28.5 pattern.

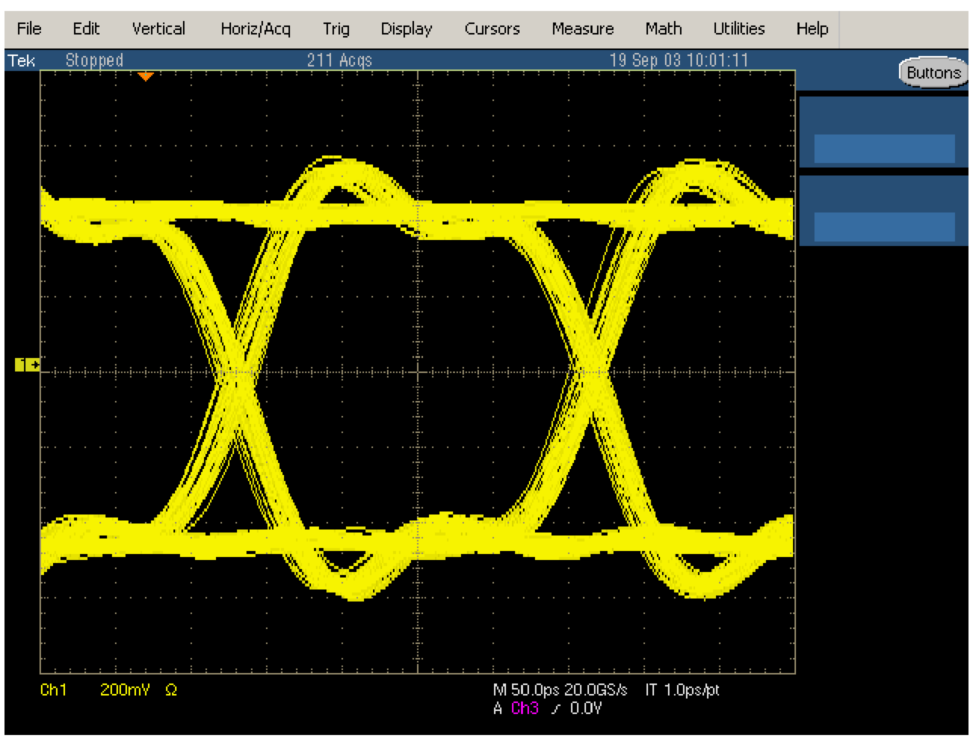


Figure 15 - Tektronix 6GHz Real Time scope waveform capture of 4.25Gb/s K28.5 pattern.

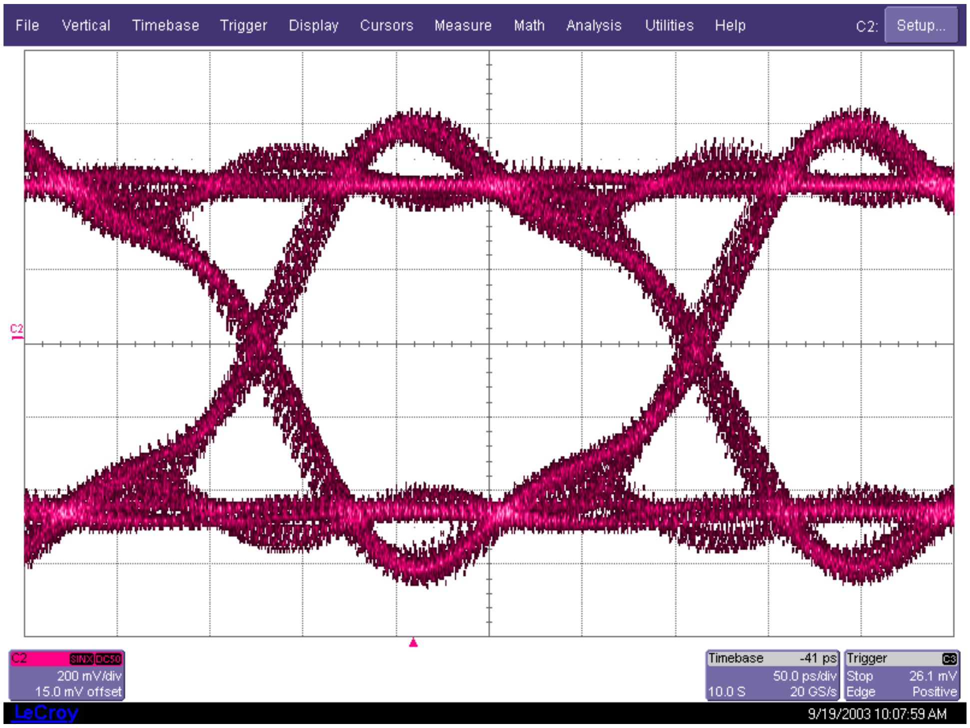


Figure 16 - Lecroy 6GHz Real Time scope waveform capture of 4.25Gb/s K28.5 pattern.

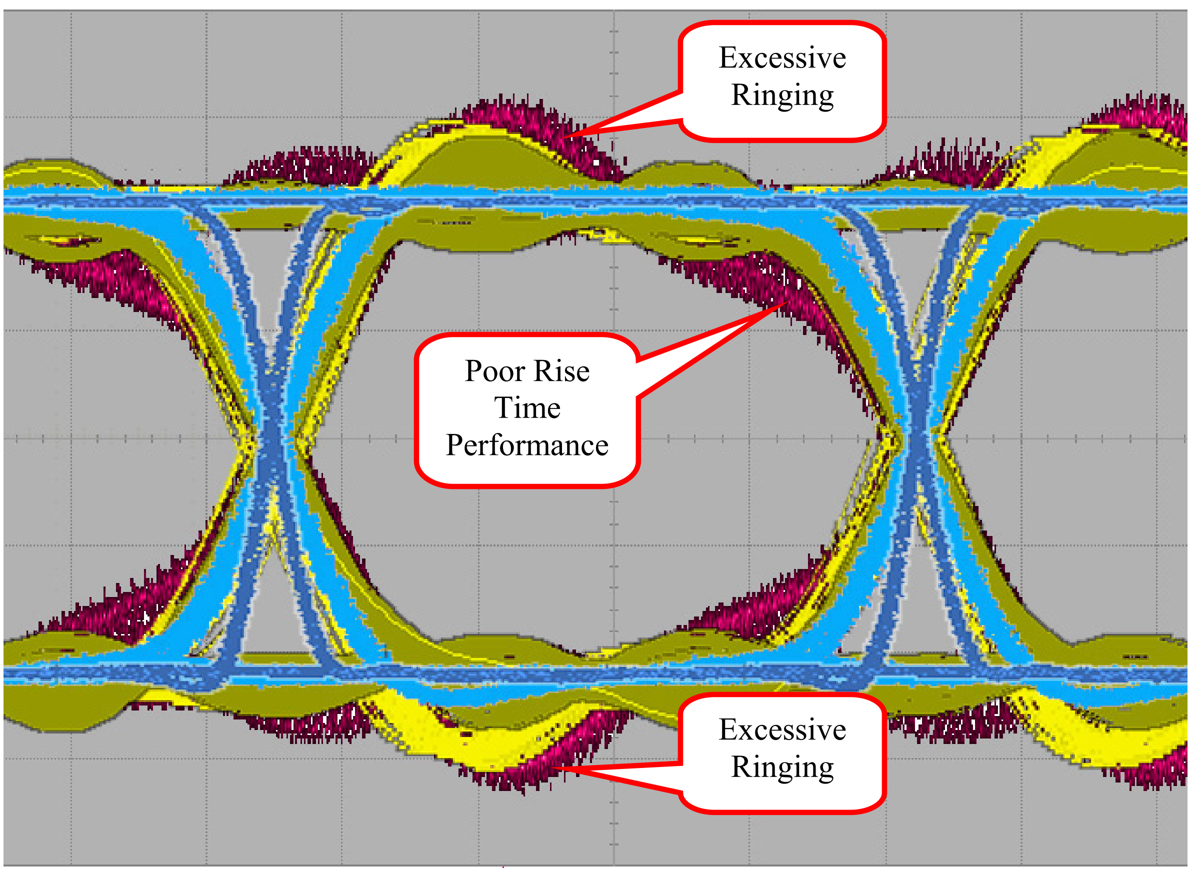


Figure 17 - Overlay of eye diagrams for Agilent 20GHz sampling scope (Dark Blue), 6GHz SIA-3000 scope (Light Blue), Agilent 6GHz (Dark Yellow), Tektronix 6604 (Light Yellow) and the Lecroy 6GHz Real Time scope (Red) for 4.25Gb/s K28.5 data stream.

## Signal Fidelity

The above plots show why analog bandwidth is a poor metric for determining system performance. The three Real Time scopes and the Wavecrest sampling scope all have 6GHz analog bandwidth. But, as you can see from the plots, the Wavecrest scope has much better overall performance because of the limited ringing, overshoot and undershoot, and overall better reproduction of the input signal. This shows that there are many attributes that make up system performance. Figure 18 shows a breakdown of these components. Analog bandwidth is only one component. Step response, resolution, and interpolation are all contributing factors in system signal fidelity. The Real Time scope poor step response and resolution cause errors in signal reproduction.

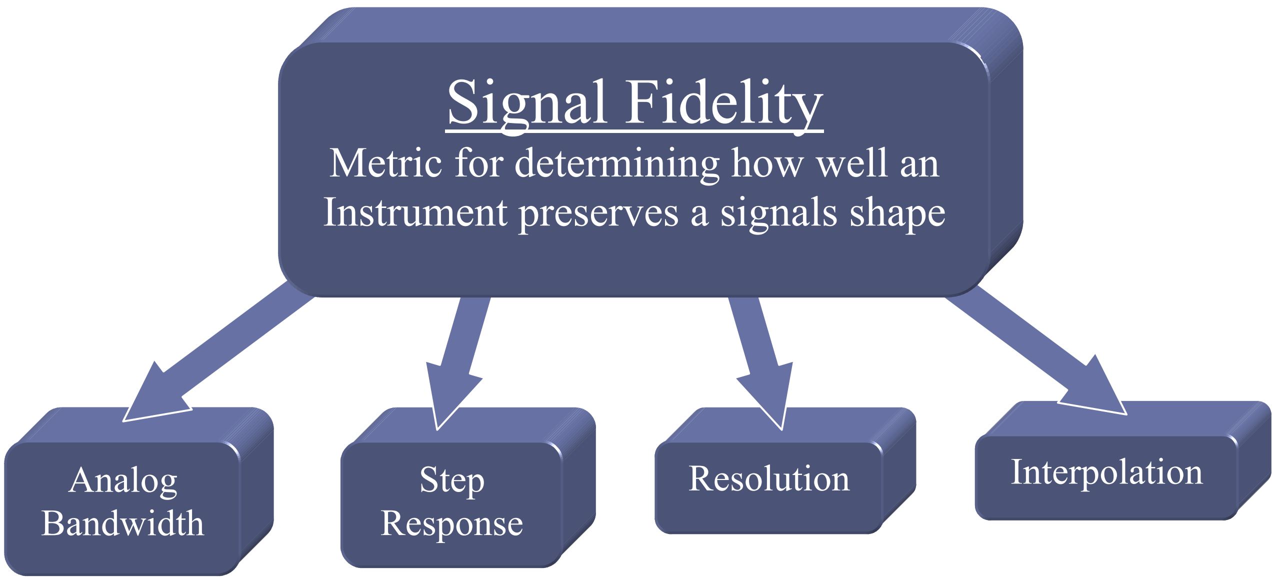


Figure 18 - Components of Signal Fidelity.

The rate of roll-off in the frequency response of each oscilloscope also effects signal fidelity. If an instrument's transfer function rolls off faster for a given –3dB point or analog bandwidth, it will attenuate higher frequencies more and have a greater effect on measurement performance of high-speed signals. Also, any non-linearity in the instruments transfer function will adversely affect the signal fidelity of the measurement system. Figure 19 shows an example of several different instrument transfer functions that all meet the same analog bandwidth. Each of these instruments will have very different performance on high-speed signals.

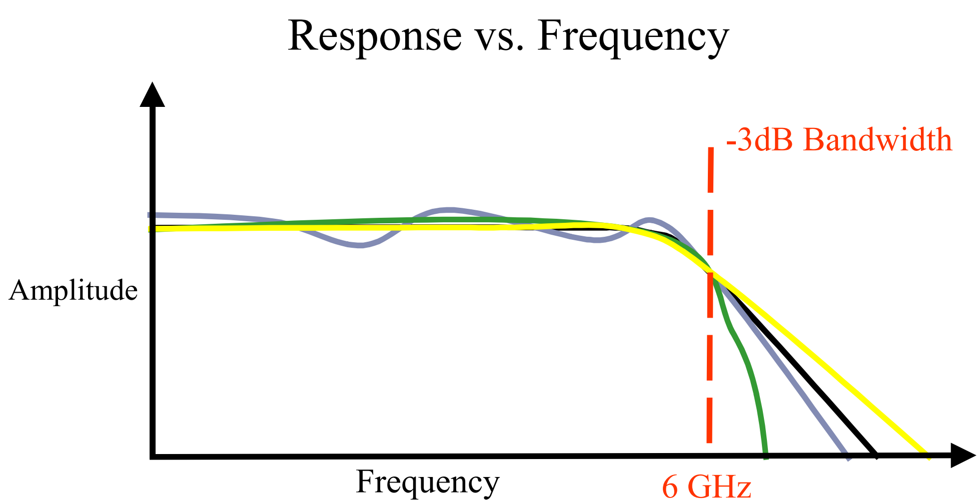


Figure 19 - Oscilloscope transfer function shows system frequency response.

## Conclusion

When using a Real Time scope, errors will be observed which is the result of the oscilloscope's inability to accurately reproduce the waveform, not the input signal. This will result in measurement errors (Rise and Fall time, Amplitude, Eye Diagram, Jitter, etc.) that are caused by the measurement instrument, not the signal under test, which can result in failing good parts. This paper shows that analog bandwidth is not a good metric for assessing system performance. Other components such as step response, resolution, and interpolation methods play a critical role in determining the instruments performance.

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