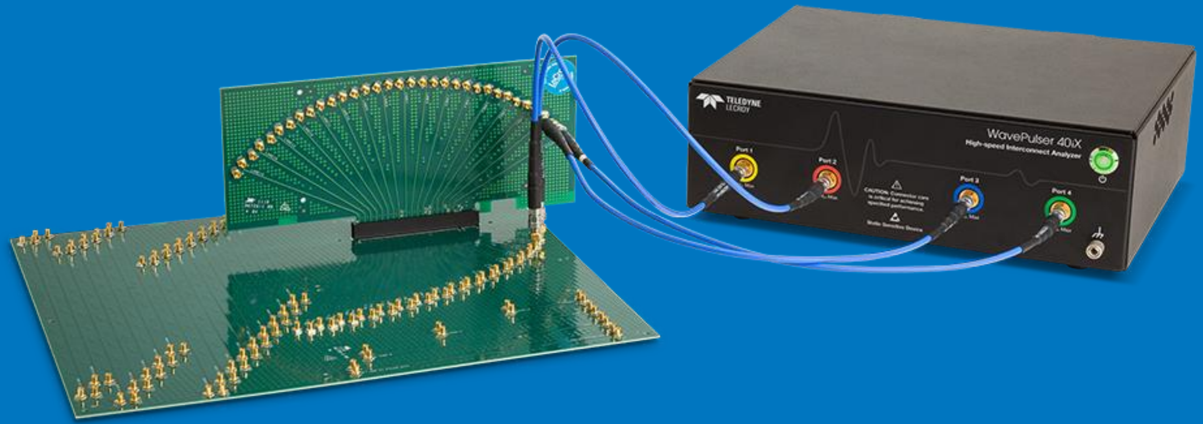
Pulse Repetition Rate and Frequency Resolution for WavePulser 40iX

High Speed Interconnect Analyzer

March-2020



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Unmatched Characterization Insight

WavePulser 40iX: Testing in frequency and time domain

Time Domain

TDR

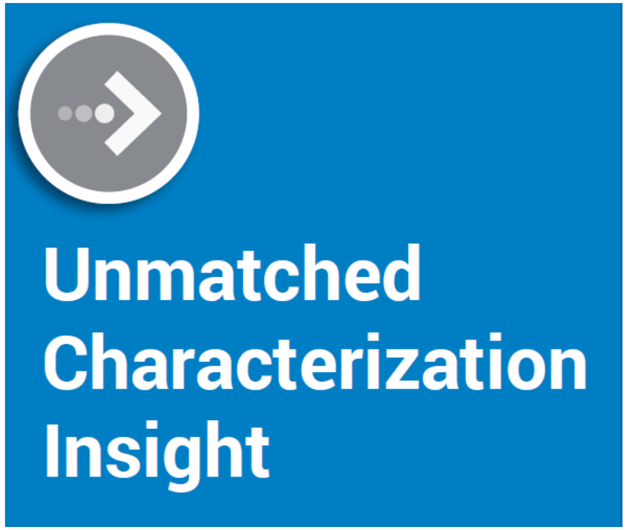
Frequency Domain

VNA

Deep Toolbox

(S-parameter de-embedding, Time Gating, Emulation equalized eye-diagram and jitter analysis)

The combination of S-parameters (frequency domain) and Impedance Profile (time domain) in a single acquisition with a deep toolbox for simulation, emulation, de-embedding and time-gating provides:



WavePulser 40iX in a nutshell

Testing in frequency and time in a single acquisition

DC to 40 GHz
Mixed-mode

S-parameters

Frequency Domain

Spatial Resolution < 1 mm
Differential and Common mode

Step and Impulse response
(rise time < 8.5 ps)
Impedance Profile

Time Domain

De-Embedding
Time Gating

Equalized eye-diagram
Jitter Analysis

Deep Toolbox

WavePulser 40iX
High Speed Interconnect Analyzer

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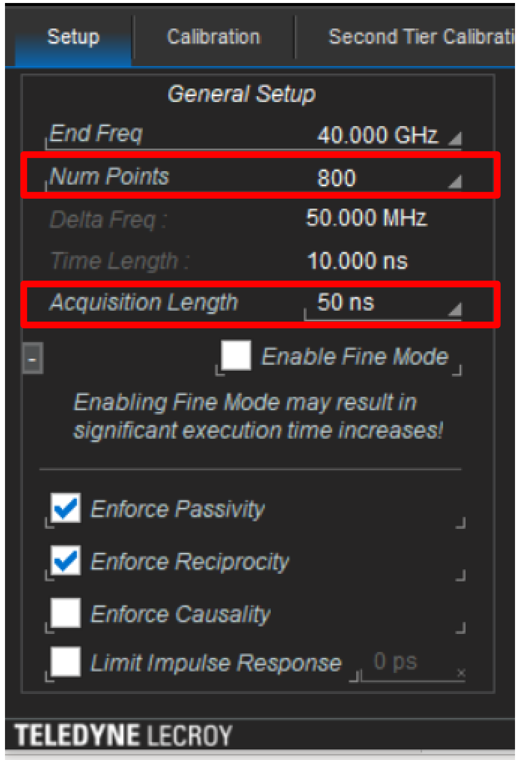
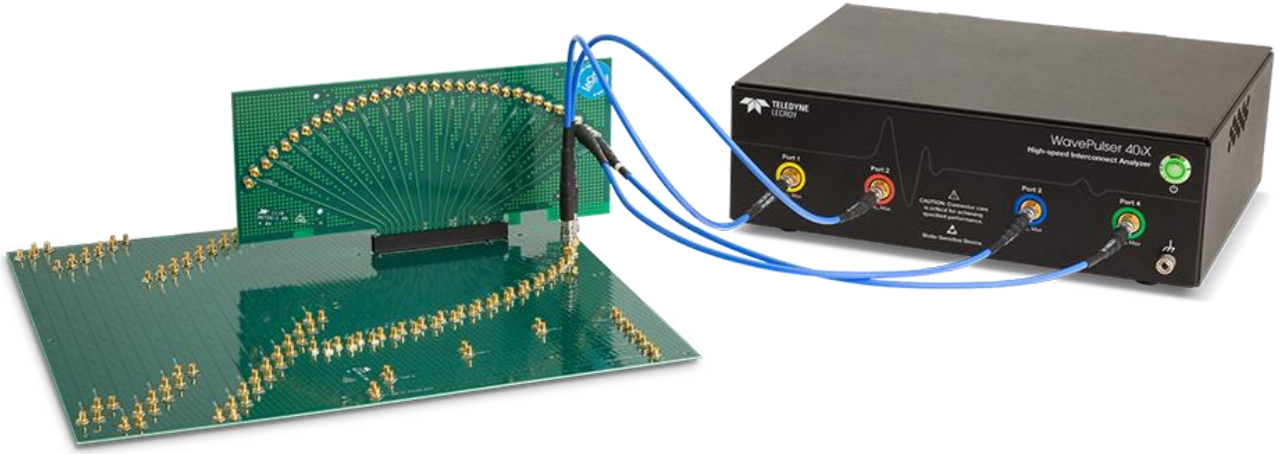
WavePulser 40iX two important settings

1. Number of Frequency Points
- which relates to the end frequency and the required frequency resolution

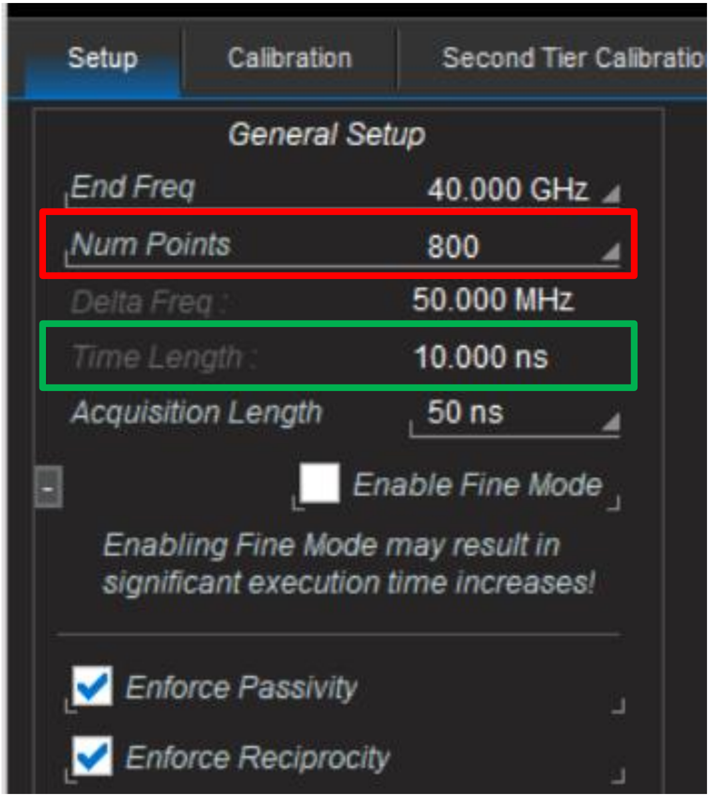
2. TDR Acquisition Length
- which relates to the pulse repetition rate



High-speed Interconnect Analyzer: the ideal single tool for high-speed hardware designers and test engineers



Number of frequency points and Impulse Response Length



We all understand the topic of frequency aliasing for time-sampled signals converted into the frequency domain: the sampling rate of the signal in the time domain determines the maximum frequency we can reconstruct.

Time aliasing is a similar behaviour in frequency sampled signals, such as S-parameters, when they are converted into the time domain: the sampling rate of the frequency domain signal (which is the frequency resolution) determines the maximum Impulse Response Length that can be reconstructed.

WavePulser 40iX uses the End Frequency and Number of Points base variables to automatically calculate the:

Impulse Response Length (Time Length)

Impulse Response Length = (1/Frequency Resolution)/2

1- Number of Frequency Points

Impulse Response Length and Electrical Length

- There is no precise or fixed relationship between the Impulse Response Length and the Electrical Length

- Rule of thumb for return loss:
  - Two transits (down and back)

- Electrical length = (Impulse Response Length) /8

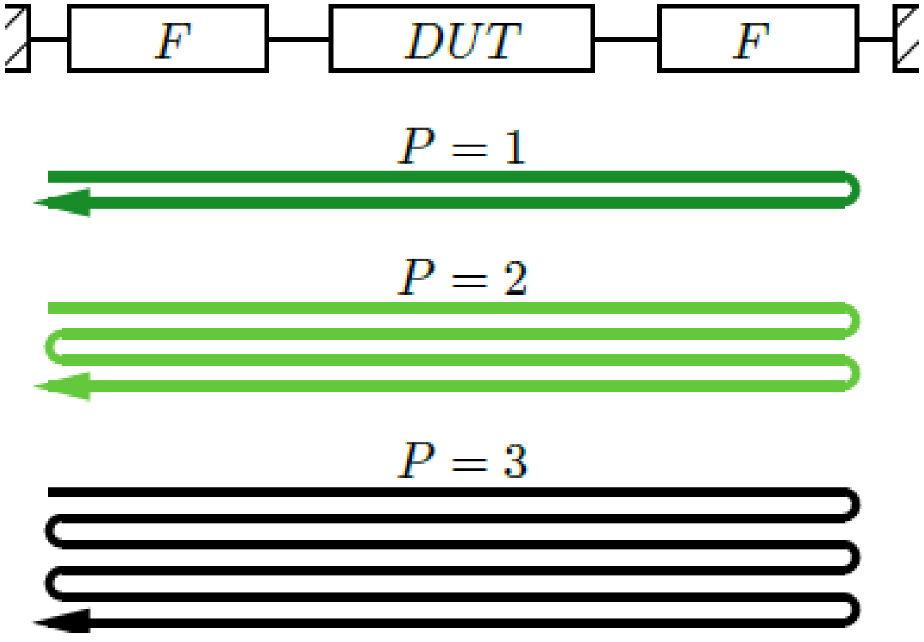
- Rule of thumb for insertion loss:
  - Three transits

- Electrical length = (Impulse Response Length)/10

1- Number of Frequency Points

Pulse Repetition Rate vs. Electrical Length

Single-Port Return Loss Measurement



(a) Return loss measurement

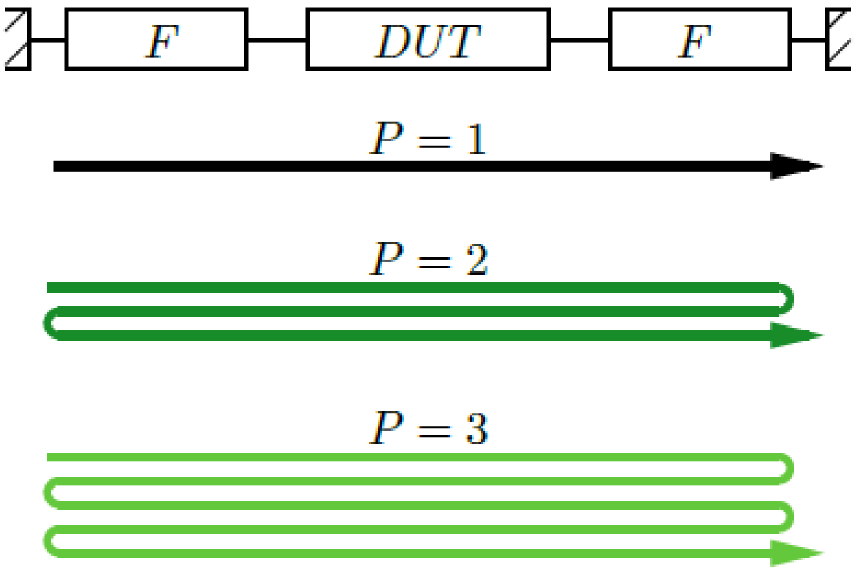
Acquisition Length	Repetition Rate	Electrical Length		
		P=1	P=2	P=3
50 ns	10 MHz	16.8 ns	6.5 ns	3.1 ns
200 ns	2.5 MHz	91.8 ns	44 ns	28.1 ns
500 ns	1 MHz	241.8 ns	119 ns	78 ns
		adequate	max performance	

✓ The default acquisition length of 50 ns is adequate for most device measurements

2- TDR Acquisition Length

Pulse Repetition Rate vs. Electrical Length

Insertion Loss Measurement



(b) Insertion loss measurement

Acquisition Length	Repetition Rate	Electrical Length		
		P=1	P=2	P=3
50 ns	10 MHz	37.5 ns	7.5 ns	1.5 ns
200 ns	2.5 MHz	187.5 ns	57.5 ns	31.5 ns
500 ns	1 MHz	487.5 ns	157.5 ns	91.5 ns
			adequate	max performance

✓ The default acquisition length of 50 ns is adequate for most device measurements

2- TDR Acquisition Length

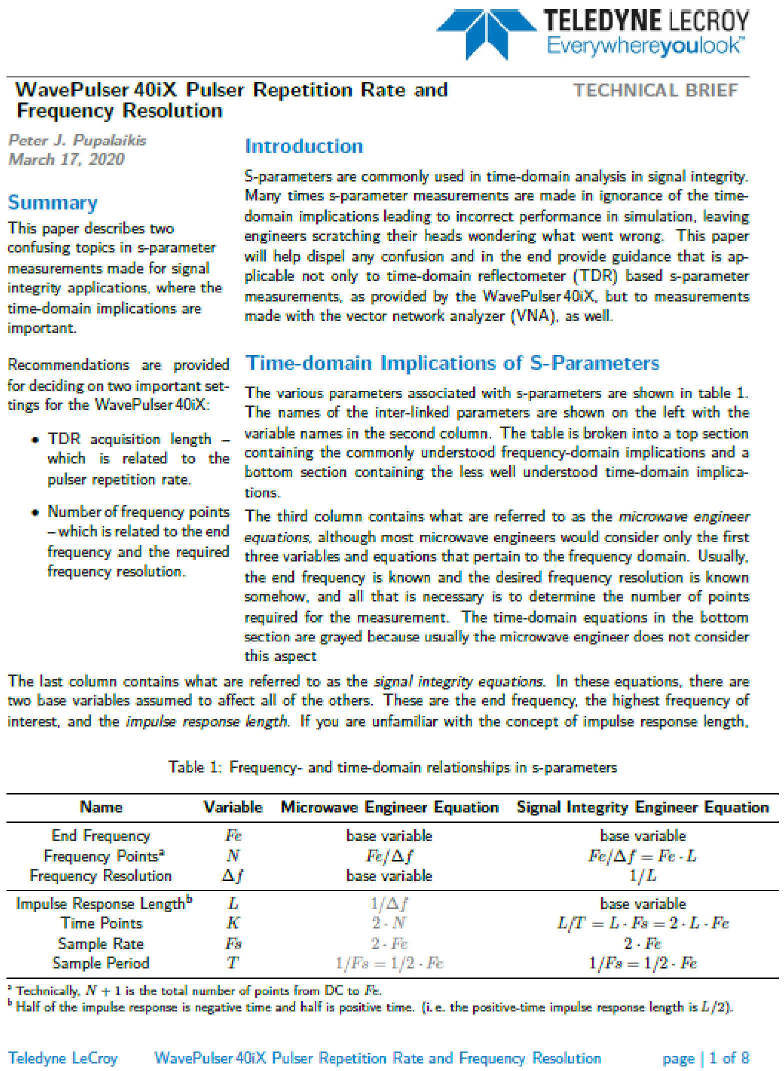
WavePulser 40iX Pulse Repetition Rate and Frequency Resolution

S-parameter frequency resolution and its relationship to impulse response length must be understood and handled properly by the signal integrity engineer

Since time-domain implications of S-parameters used in signal integrity analysis is so important, one should understand the electrical length limitations of the measurement instruments and the controls such as the acquisition length mode of the WavePulser 40iX

That being said, the default acquisition length of 50 ns is adequate for most device measurements, with the longest mode supporting the measurement of devices up to 200ns in electrical length

To know more go to
https://cdn.teledynelecroy.com/files/appnotes/pulse-repetition-rate-and-frequency-resolution.pdf



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WavePulser 40iX Pulser Repetition Rate and Frequency Resolution TECHNICAL BRIEF

Peter J. Pupalaikis
March 17, 2020

Summary

This paper describes two confusing topics in s-parameter measurements made for signal integrity applications, where the time-domain implications are important.

Recommendations are provided for deciding on two important settings for the WavePulser 40iX:

- TDR acquisition length – which is related to the pulser repetition rate.
- Number of frequency points – which is related to the end frequency and the required frequency resolution.

Introduction

S-parameters are commonly used in time-domain analysis in signal integrity. Many times s-parameter measurements are made in ignorance of the time-domain implications leading to incorrect performance in simulation, leaving engineers scratching their heads wondering what went wrong. This paper will help dispel any confusion and in the end provide guidance that is applicable not only to time-domain reflectometer (TDR) based s-parameter measurements, as provided by the WavePulser 40iX, but to measurements made with the vector network analyzer (VNA), as well.

Time-domain Implications of S-Parameters

The various parameters associated with s-parameters are shown in table 1. The names of the inter-linked parameters are shown on the left with the variable names in the second column. The table is broken into a top section containing the commonly understood frequency-domain implications and a bottom section containing the less well understood time-domain implications.

The third column contains what are referred to as the *microwave engineer equations*, although most microwave engineers would consider only the first three variables and equations that pertain to the frequency domain. Usually, the end frequency is known and the desired frequency resolution is known somehow, and all that is necessary is to determine the number of points required for the measurement. The time-domain equations in the bottom section are grayed because usually the microwave engineer does not consider this aspect

The last column contains what are referred to as the *signal integrity equations*. In these equations, there are two base variables assumed to affect all of the others. These are the end frequency, the highest frequency of interest, and the *impulse response length*. If you are unfamiliar with the concept of impulse response length,

Table 1: Frequency- and time-domain relationships in s-parameters

Name	Variable	Microwave Engineer Equation	Signal Integrity Engineer Equation
End Frequency	Fe	base variable	base variable
Frequency Points[a]	N	$Fe/\Delta f$	$Fe/\Delta f = Fe \cdot L$
Frequency Resolution	Δf	base variable	$1/L$
Impulse Response Length[b]	L	$1/\Delta f$	base variable
Time Points	K	$2 \cdot N$	$L/T = L \cdot Fs = 2 \cdot L \cdot Fe$
Sample Rate	Fs	$2 \cdot Fe$	$2 \cdot Fe$
Sample Period	T	$1/Fs = 1/2 \cdot Fe$	$1/Fs = 1/2 \cdot Fe$

[a] Technically, $N + 1$ is the total number of points from DC to Fe.
[b] Half of the impulse response is negative time and half is positive time. (i.e. the positive-time impulse response length is $L/2$).

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