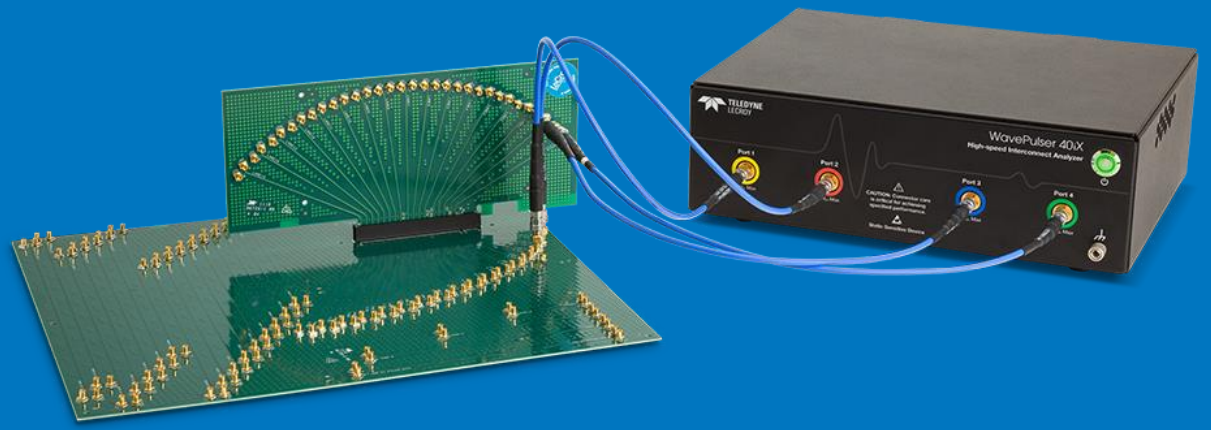
WavePulser 40iX Dynamic Range

High Speed Interconnect Analyzer

April-2020



Giuseppe Leccia
Business Development Manager

TELEDYNE LECROY
Everywhereyoulook™

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:

Unmatched Characterization Insight

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

Unmatched Characterization Insight

WavePulser 40iX Dynamic Range

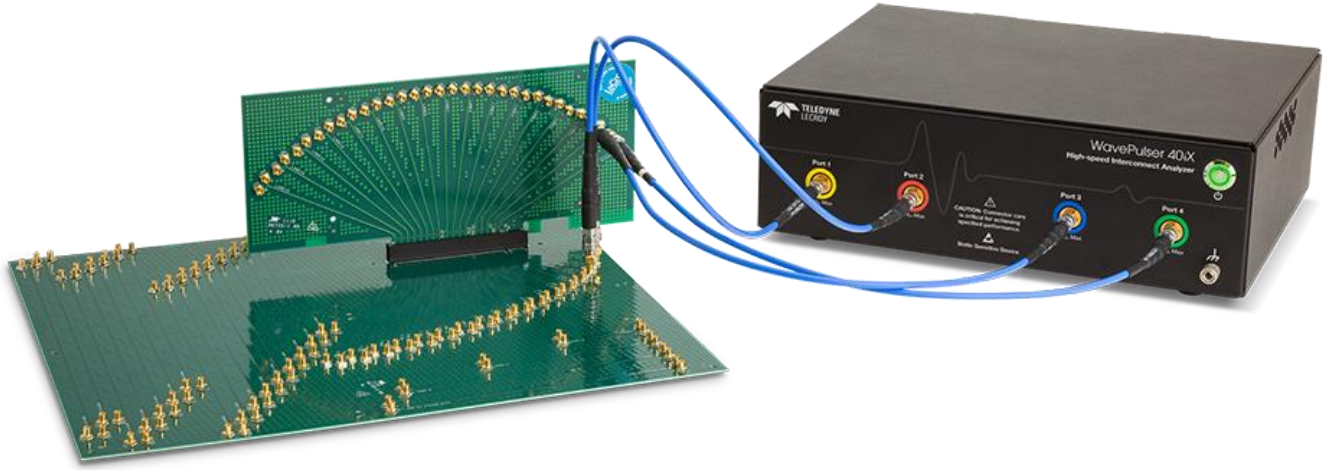
- Dynamic Range refers to the signal-to-noise ratio (SNR) of the network system, precisely the ratio of the incident power to the noise power

- Dynamic Range is defined at each frequency

- Dynamic Range is a Vector Network Analyzer (VNA) banner specification

- The question "what is the dynamic range?" when referring to TDRs making S-parameter measurements, is not very well understood. It is similar to the question "what is the spatial resolution?" when referring to VNAs making impedance profile measurements

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



Dynamic Range of WavePulser 40iX compares to the SPARQ

WavePulser 40iX
introduced in 2019

SPARQ-4004E
produced until 2018

- many improvements made in the WavePulser 40iX product including dynamic range (nearly 10 dB improvement @40 GHz)
- WavePulser 40iX uses an impulse instead of a step in the SPARQ.
- The advantage of the impulse is that its frequency content is ideally flat while the frequency content of the step is proportional to 1/f
- WavePulser 40iX is three times faster
- WavePulser 40iX sample rate 100 MS/s vs. 10 MS/s for SPARQ adds 10 dB dynamic range.
- WavePulser 40iX employs a pulser/sampler for each port, whereas the SPARQ employed one pulser/sampler.

WavePulser 40iX Dynamic Range

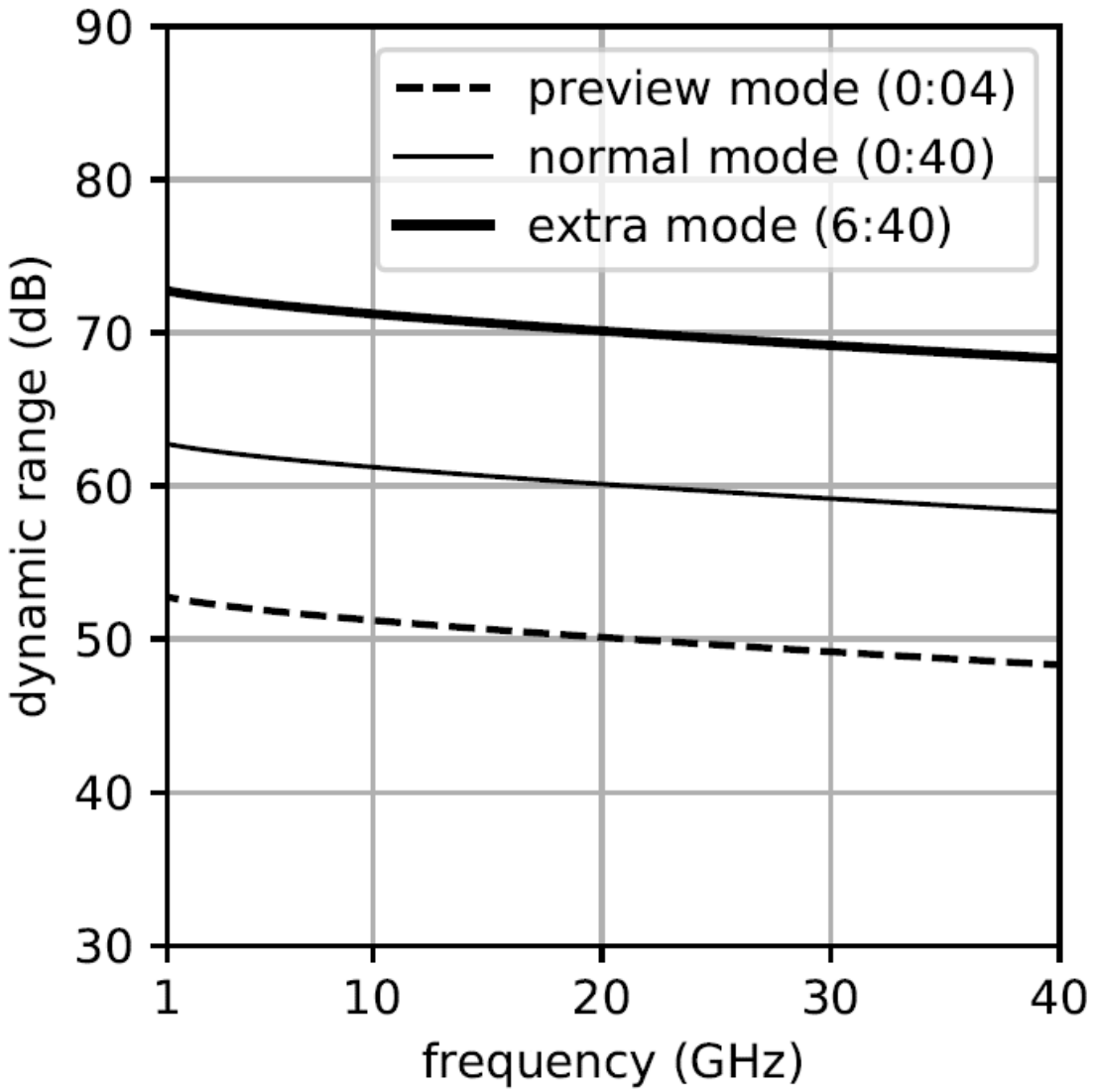
- Calculated accordingly to the following formula:

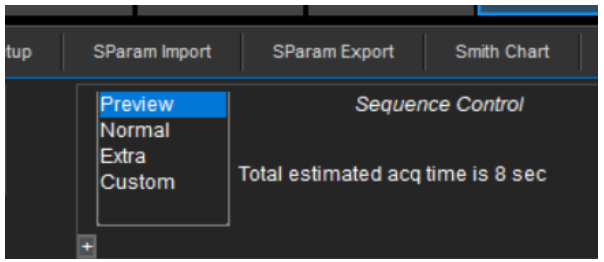
$$SNR(f) = 10 \cdot \log\left(\frac{f_{bw}}{F_{se/2}}\right) - \mathcal{N} + \begin{cases} 20 \cdot \log\left(\frac{A}{f}\right) - 3 & \text{step} \\ 20 \cdot \log(A) + 13 & \text{impulse} \end{cases} + 10 \cdot \log\left(\frac{F_{sa} \cdot T_w}{T_d^2}\right) - 10 \cdot \log(frac) + P(f) + 2 \cdot F(f).$$

- the first term deals with the definition of the overall noise only
- the second term deals with steps vs. impulses
- the third term deals with the acquisition speed
- the fourth term deals with the effect of denoising
- the last two terms deal with the response of the pulser/sampler and the fixturing/cabling effect:

$$F(f) = (F + C) \cdot \left(-0.133 \cdot \sqrt{f/1\,\text{GHz}} - 0.00404 \cdot f/1\,\text{GHz}\right)$$

WavePulser 40iX Dynamic Range

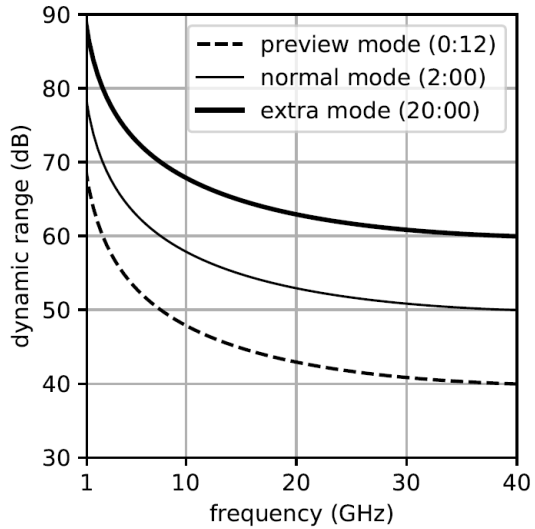




- Total measurement time (acquisition time) is provided
- WavePulser is three times faster because it employs a pulser/sampler per port, whereas the SPARQ employed one pulser/sampler.
- Plots are shown starting from 1 GHz with the general expectation that dynamic range is constant from DC to 1 GHz

- WavePulser 40iX dynamic range are shown to be more than adequate for signal integrity measurements.
- Three curves shown for preview, normal and extra acquisition mode

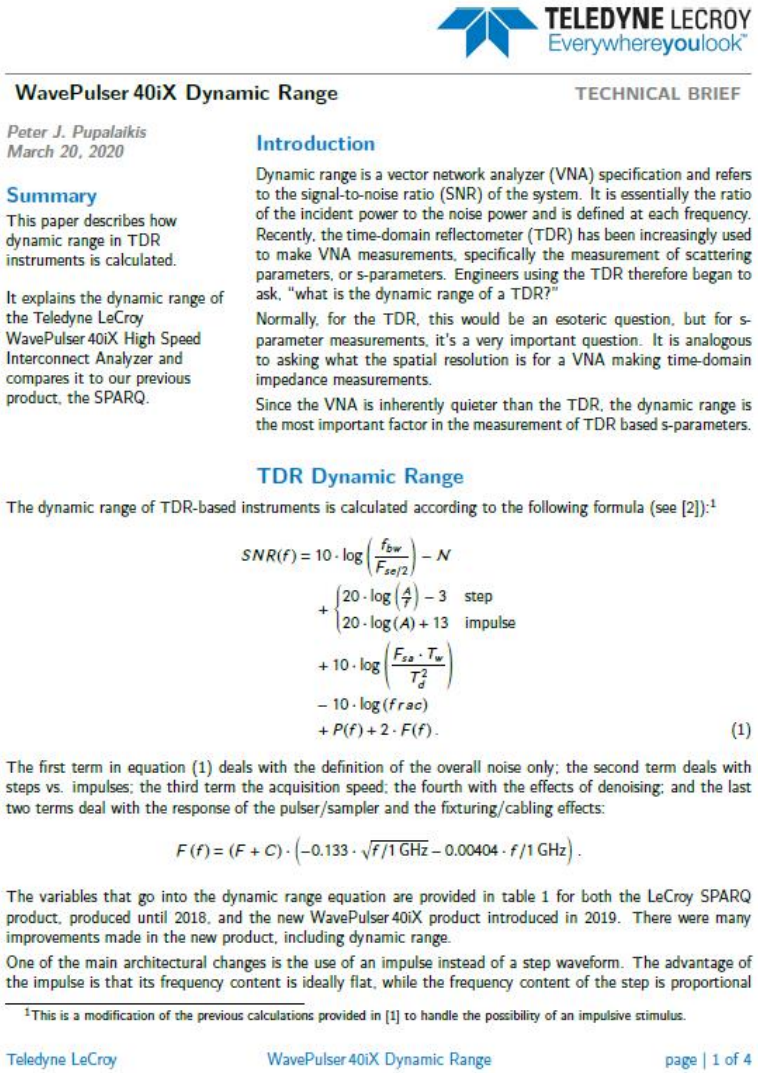
SPARQ-4004 Dynamic Range



WavePulser 40iX Dynamic Range

- The WavePulser provides nearly 10 dB dynamic range improvement at 40 GHz over the SPARQ
- Both the old SPARQ product and the new WavePulser 40iX provide the highest dynamic range TDR based s-parameter measurements instruments
- WavePulser 40iX dynamic range are shown to be more than adequate for signal integrity measurements.

To know more go to:
https://teledynelecroy.com/doc/wavepulser-dynamic-range



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Everywhereyoulook™

WavePulser 40iX Dynamic Range TECHNICAL BRIEF

Peter J. Pupalaikis
March 20, 2020

Summary

This paper describes how dynamic range in TDR instruments is calculated.

It explains the dynamic range of the Teledyne LeCroy WavePulser 40iX High Speed Interconnect Analyzer and compares it to our previous product, the SPARQ.

Introduction

Dynamic range is a vector network analyzer (VNA) specification and refers to the signal-to-noise ratio (SNR) of the system. It is essentially the ratio of the incident power to the noise power and is defined at each frequency. Recently, the time-domain reflectometer (TDR) has been increasingly used to make VNA measurements, specifically the measurement of scattering parameters, or s-parameters. Engineers using the TDR therefore began to ask, "what is the dynamic range of a TDR?"

Normally, for the TDR, this would be an esoteric question, but for s-parameter measurements, it's a very important question. It is analogous to asking what the spatial resolution is for a VNA making time-domain impedance measurements.

Since the VNA is inherently quieter than the TDR, the dynamic range is the most important factor in the measurement of TDR based s-parameters.

TDR Dynamic Range

The dynamic range of TDR-based instruments is calculated according to the following formula (see [2]):[1]

$$\begin{aligned} SNR(f) = {} & 10 \cdot \log\left(\frac{f_{bw}}{F_{se/2}}\right) - N \\ & + \begin{cases} 20 \cdot \log\left(\frac{A}{T}\right) - 3 & \text{step} \\ 20 \cdot \log(A) + 13 & \text{impulse} \end{cases} \\ & + 10 \cdot \log\left(\frac{F_{sa} \cdot T_w}{T_d^2}\right) \\ & - 10 \cdot \log(frac) \\ & + P(f) + 2 \cdot F(f). \end{aligned} \quad (1)$$

The first term in equation (1) deals with the definition of the overall noise only; the second term deals with steps vs. impulses; the third term the acquisition speed; the fourth with the effects of denoising; and the last two terms deal with the response of the pulser/sampler and the fixturing/cabling effects:

$$F(f) = (F + C) \cdot \left(-0.133 \cdot \sqrt{f/1\,\text{GHz}} - 0.00404 \cdot f/1\,\text{GHz}\right).$$

The variables that go into the dynamic range equation are provided in table 1 for both the LeCroy SPARQ product, produced until 2018, and the new WavePulser 40iX product introduced in 2019. There were many improvements made in the new product, including dynamic range.

One of the main architectural changes is the use of an impulse instead of a step waveform. The advantage of the impulse is that its frequency content is ideally flat, while the frequency content of the step is proportional

[1] This is a modification of the previous calculations provided in [1] to handle the possibility of an impulsive stimulus.

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