APPLICATION NOTE

WavePulser 1X Short/Open and 2X Thru With Gating De-embedding

February 12, 2026

Summary

This application note explains how to use WavePulser 40iX to estimate gating parameters for de-embedding from S-parameters measured on a connected structure terminated in a short or open.

Introduction

This application note addresses situations where a conventional 2X Thru fixture cannot be built, instead leveraging a 1X Short or 1X Open fixture to measure 2X Thru de-embedding S-parameters with the WavePulser 40iX.

The 1X Short/Open feature uses fixture measurements to extract gating parameters—length and loss—which can then be applied to de-embed the fixture using WavePulser's gating capability.

Later in this application note, we introduce the concept of 2X Thru with Gating de-embedding—a method that combines the 1X Short/Open approach with the fixture splitting described in "Mastering WavePulser 40iX 2X Thru De-embedding", effectively enabling de-embedding based on both S-parameter measurements and impedance profile analysis.

1X Short/Open De-embedding for Single-Ended Traces

This feature is used to figure out the gating parameters for de-embedding. The DUT + fixture configuration can be either a 1-port measurement or *N*-port measurement with the assumption that the fixture properties (or trace properties) are the same for all the ports.

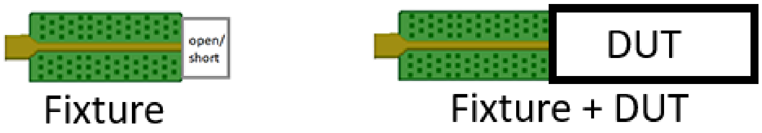


Figure 1: 1X Short/Open fixture for a single-ended trace, 1-port configuration

Figure 1 illustrates a scenario where both the fixture and the combined fixture + DUT are 1-port measurements. The de-embedding task is to determine the gating parameters of the fixture to accurately remove its influence and derive 1-port DUT S-parameters.

Figure 2 illustrates a scenario where the same type of fixture is now connected to a 2-port DUT.

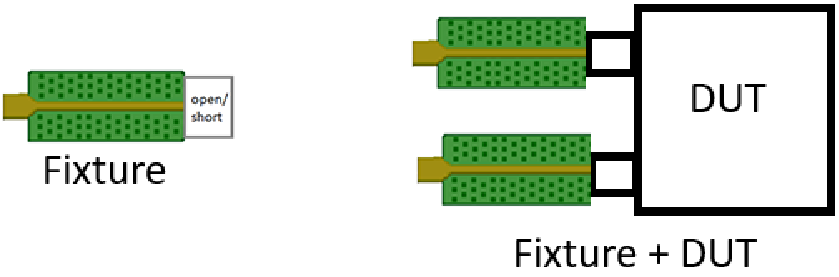
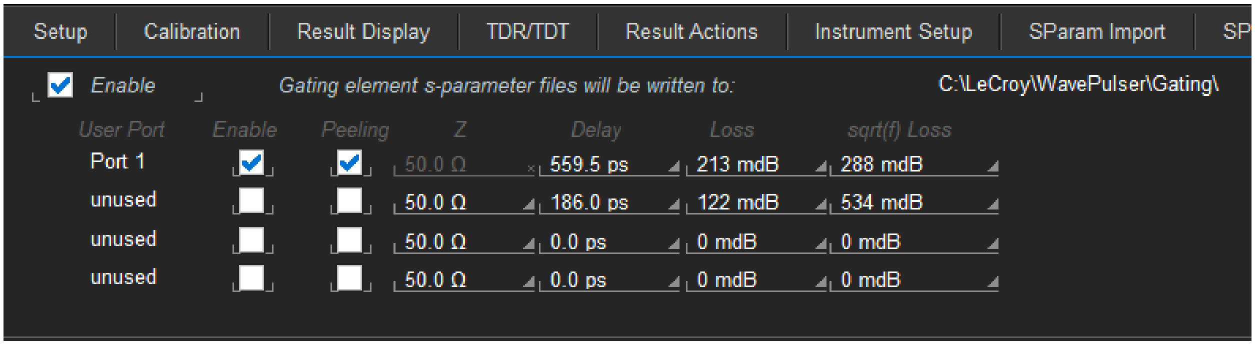


Figure 2: 1X Short/Open fixture for a single-ended trace, 2-port configuration

In this case, de-embedding involves using a single fixture measurement to extract gating parameters and applying the same parameters to both ports of the DUT + fixture setup. Loss parameters are derived from the fixture, while length and impedance profile can be adjusted based on DUT + fixture data. Further details follow in the process description.

This approach assumes no coupling between the two traces connected to the DUT. When that condition holds, the same methodology applies to any *N*-port DUT. The gating parameters calculated from the measurement are shown in Figure 3 below.



☑ *Enable*   *Gating element s-parameter files will be written to:* C:\LeCroy\WavePulser\Gating\

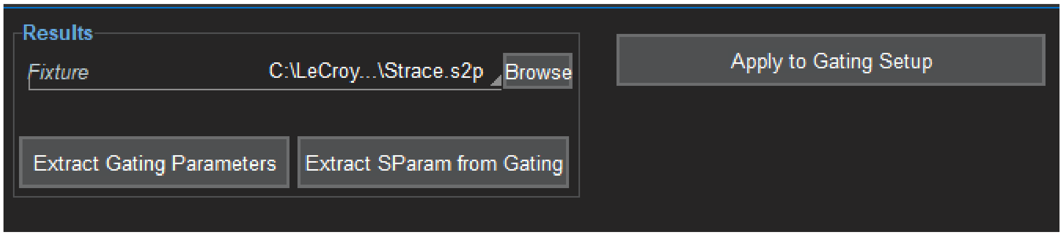
User Port	*Enable*	*Peeling*	*Z*	*Delay*	*Loss*	*sqrt(f) Loss*
Port 1	☑	☑	50.0 Ω	559.5 ps	213 mdB	288 mdB
unused	☐	☐	50.0 Ω	186.0 ps	122 mdB	534 mdB
unused	☐	☐	50.0 Ω	0.0 ps	0 mdB	0 mdB
unused	☐	☐	50.0 Ω	0.0 ps	0 mdB	0 mdB

Figure 3: Gating parameters derived from 1X Short/Open measurement of single-ended, 1-port trace

Further details on gating are provided in the application note "Time-Domain Techniques for De-embedding and Impedance Peeling". In summary, gating involves fitting a transmission line model where S21 loss is expressed as $a\cdot f + b\cdot\sqrt{f}$, with *a* and *b* representing the linear and square-root loss terms, respectively. Frequency is denoted by *f*, and the delay parameter corresponds to line length. When peeling is enabled, the impedance profile derived from measured S11, and S21 model is automatically adjusted accordingly.

To determine the *a* and *b* coefficients, a least-squares fit is performed on the S11 (in dB) measurement of the fixture. Note that S11 contains round-trip loss, while the model's S21 requires only one-way loss—this is accounted for when estimating *a* and *b*.

Figure 4 illustrates the output section of the 2X Thru dialog when using the 1X Short/Open method.



Fixture C:\LeCroy...\Strace.s2p

Figure 4: Output section of 2X Thru dialog when using the 1X Short/Open method

The 'Extract Gating Parameters' button performs two actions:

- Determines gating parameters from the fixture measurement
- Creates 2-port S-parameters of the model that is created from the gating parameters

'Apply to Gating Setup' populates the Gating dialog (shown above), enabling fine-tuning of the parameters to further enhance methodological accuracy.

The gating parameters generated by the algorithm may not be fully accurate initially. We anticipate fine-tuning these parameters by leveraging WavePulser's TDR-based technology to avoid excessive correction. This approach is more intuitive than manually adjusting parameters to counter overcorrection. After fine-tuning, use the ‘Extract SParam from Gating’ button to create an S-parameter file for the updated model. This file serves two purposes: first, it can be used in external tools for de-embedding; second, it provides a reference to assess parameter accuracy.

If the DUT includes multiple fixtures, the same gating parameters must be applied to all ports. The algorithm derives parameters from a one-port measurement and populates that port when you select ‘Apply to Gating Setup.’ For additional ports, you may need to manually enter the remaining parameters.

1X Short/Open De-embedding for Differential Traces

When working with coupled differential traces, the 1X Short/Open fixture is a 2-port device. The figure below shows one possible 1X Short/Open fixture + DUT configuration where the coupled lines lead to DUT and exit from the DUT to the WavePulser. The assumption is that the measured fixture has identical characteristics for both halves in the fixture + DUT configuration.

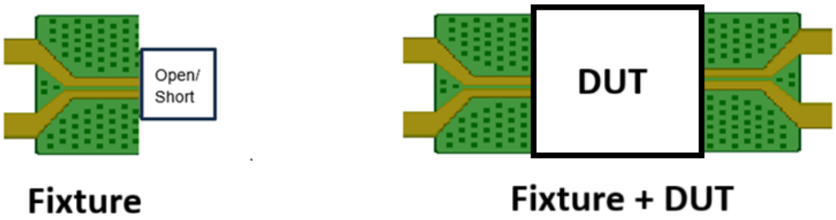
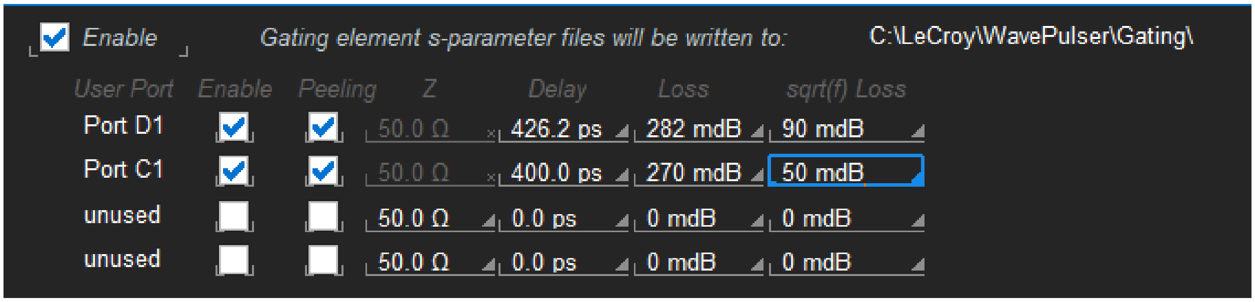


Figure 5: 1X Short/Open fixture for differential trace

The 1X Short/Open algorithm processes the 2-port measurement, converts it to mixed mode if initially single ended, then applies the same 1-port method described earlier to differential and common-mode measurements individually.

In this mode, the gating parameters are computed for differential and common mode ports, so the only way to apply this to existing measurement is if the setup is for mixed mode. The ‘Apply to Gating Setup’ button on the 2X Thru dialog will be grayed out if the measurement setup is single ended.

When the measurement is in mixed mode and you select ‘Apply to Gating Setup,’ the gating parameters are transferred to the setup as shown in the figure below. Typically, values for differential and common-mode ports are similar, though here they are varied for illustration.



☑ Enable Gating element s-parameter files will be written to: C:\LeCroy\WavePulser\Gating\

User Port	Enable	Peeling	Z	Delay	Loss	sqrt(f) Loss
Port D1	☑	☑	50.0 Ω	426.2 ps	282 mdB	90 mdB
Port C1	☑	☑	50.0 Ω	400.0 ps	270 mdB	50 mdB
unused	☐	☐	50.0 Ω	0.0 ps	0 mdB	0 mdB
unused	☐	☐	50.0 Ω	0.0 ps	0 mdB	0 mdB

Figure 6: Gating parameters derived from a differential 1X Short/Open measurement

The 1X Short/Open algorithm calculates gating parameters only for ports D1 and C1, as defined by the fixture. After fine-tuning, clicking ‘Extract SParam from Gating’ on the 2X Thru dialog generates a 4-port fixture S-parameter file in single-ended mode. The port numbering is illustrated by Figure 7 below.

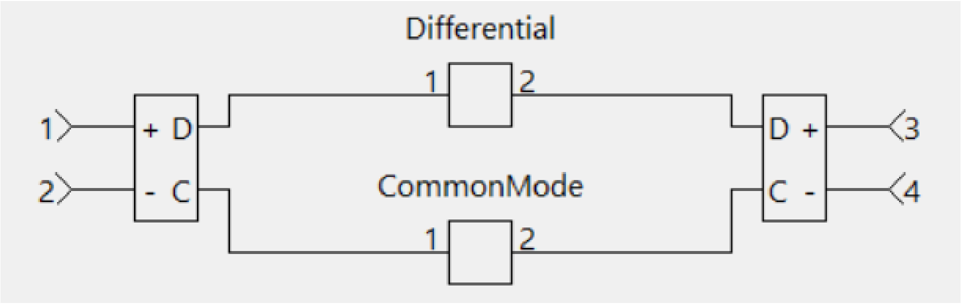
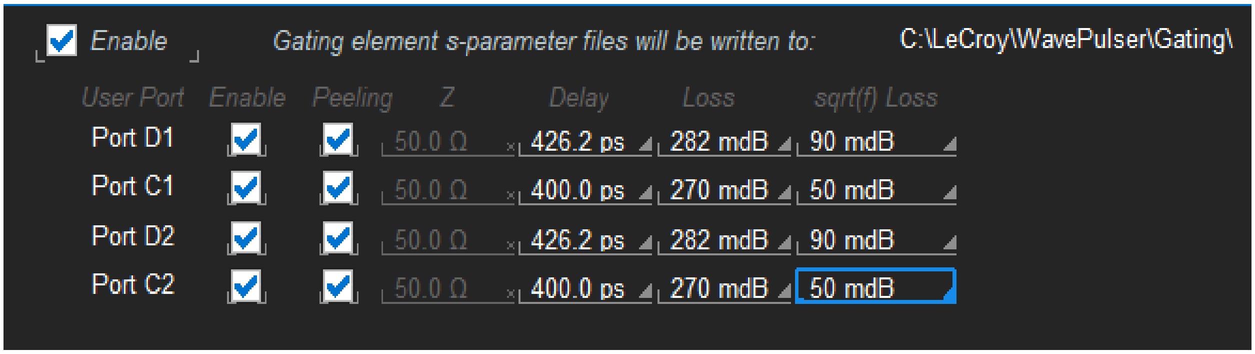


Figure 7: D1 and C1 port numbering of differential 1X Short/Open measurement

The 1X Short/Open algorithm generates both differential and common-mode 2-port S-parameters. These can then be exported as a 4-port S-parameter file for use in external tools if required.

If the DUT is a 4-port device, gating parameters for D2 and C2 must be entered manually on the Gating dialog prior to extracting gating paramaters. These values typically match D1 and C1 but can differ based on the impedance profile of the fixture + DUT measurement. The Figure 8 below shows the Gating UI updated for a 4-port DUT + fixture configuration.



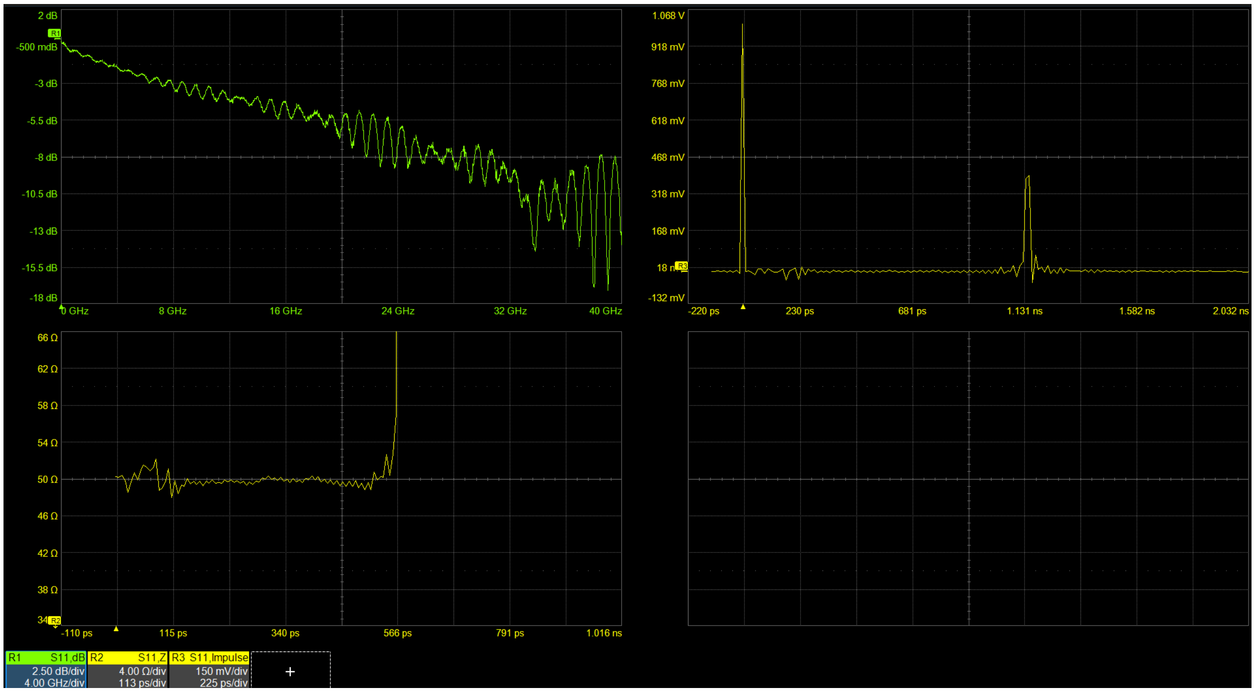
☑ Enable   Gating element s-parameter files will be written to: C:\LeCroy\WavePulser\Gating\

User Port	Enable	Peeling	Z	Delay	Loss	sqrt(f) Loss
Port D1	☑	☑	50.0 Ω	426.2 ps	282 mdB	90 mdB
Port C1	☑	☑	50.0 Ω	400.0 ps	270 mdB	50 mdB
Port D2	☑	☑	50.0 Ω	426.2 ps	282 mdB	90 mdB
Port C2	☑	☑	50.0 Ω	400.0 ps	270 mdB	50 mdB

Figure 8: Gating parameters calculated for ports D1 and C1 of differential 1X Short/Open

Use Case: Fine-tuning 1X Short/Open Gating Parameters

Figure 9 shows a single-ended 1X Short/Open fixture’s S11 in dB, impulse response and impedance profile. From this measurement, we will extract the gating parameters, from which the software generates 2-port S-parameters for the model built from the gating parameters.



R1 S11,dB 2.50 dB/div 4.00 GHz/div

R2 S11,Z 4.00 Ω/div 113 ps/div

R3 S11,Impulse 150 mV/div 225 ps/div

Figure 9: S11 in dB, impulse response and impedance profile for 1X Short/Open measurement of single-ended trace

Next, we import these S-parameters to compare with the original measurement. One must note that the S11 shown above shows two-way loss – the signal going to the open and coming back, whereas the 2-port model’s S21 will represent the one-way loss. So, we need to halve the vertical axis to compare the loss. Figure 10 below compares the dB value of the 1X Open, the impulse response and the impedance profile.

Also note that the 1X Open measurement consists of the fully reflected signal, which introduces the ripples in the S11 dB measurement. The fixture S21 has no such reflection and hence is a much smoother line. Here we just want to make sure the fitted curve looks reasonable.

In Figure 10, the memory traces represent the 1X Open fixture, while the R-traces correspond to the model’s S-parameters. The green trace aligns well with the loss, though adding a slight √f loss could improve low-frequency correlation. The impedance profile shows a reasonable match, with at most a minor ambiguity.

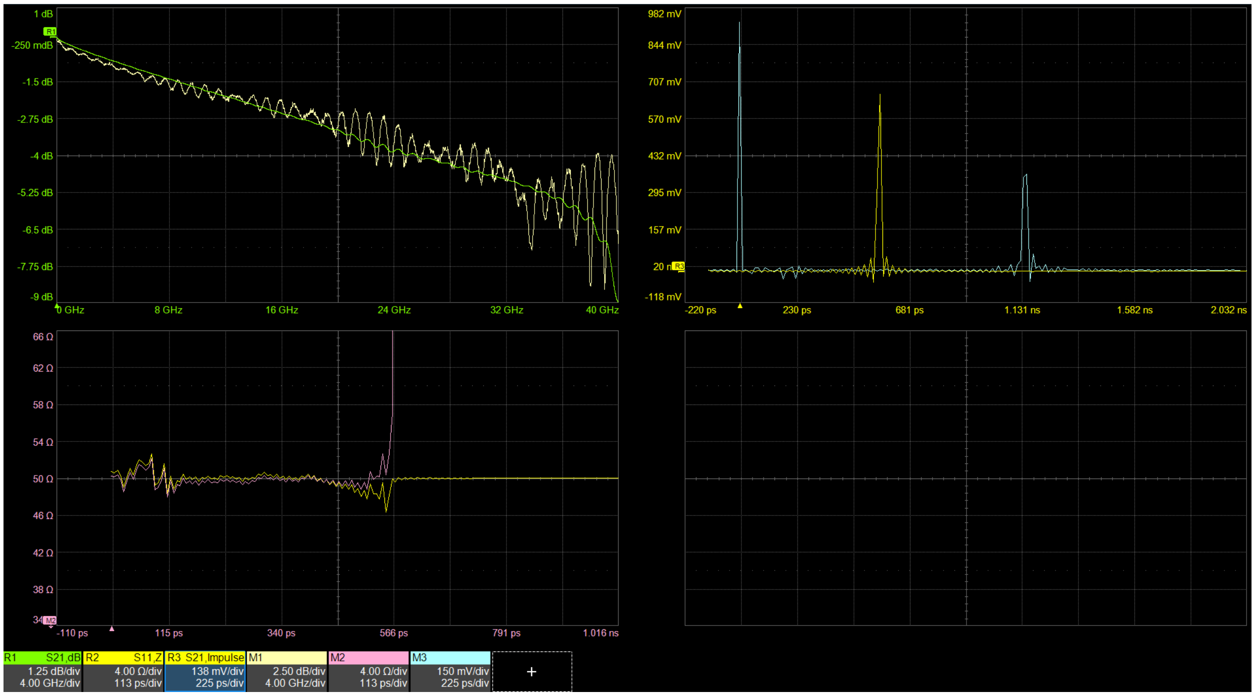
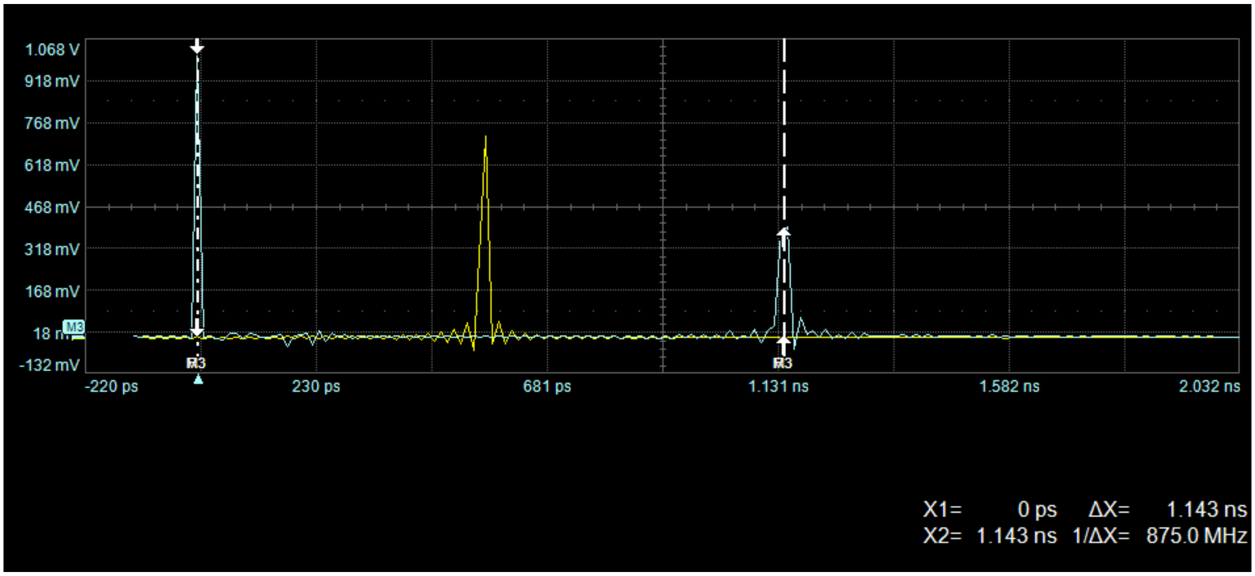


Figure 10: Comparison of S11 in dB, impulse response and impedance profile

To confirm length, compare the delta between the two impulses for the open—the reflection return time. The S21 impulse should fall exactly between them, which can be verified using cursors (as shown in Figure 11)



X1= 0 ps ΔX= 1.143 ns
X2= 1.143 ns 1/ΔX= 875.0 MHz

Figure 11: The S21 impulse should precisely align between the two open-reflection impulses

In Figure 11, the delay between the two impulses is 1.143 ns, so the yellow impulse should occur near 571 ps. In Figure 12, it appears at about 561 ps, indicating the delay can be increased by roughly 10 ps.

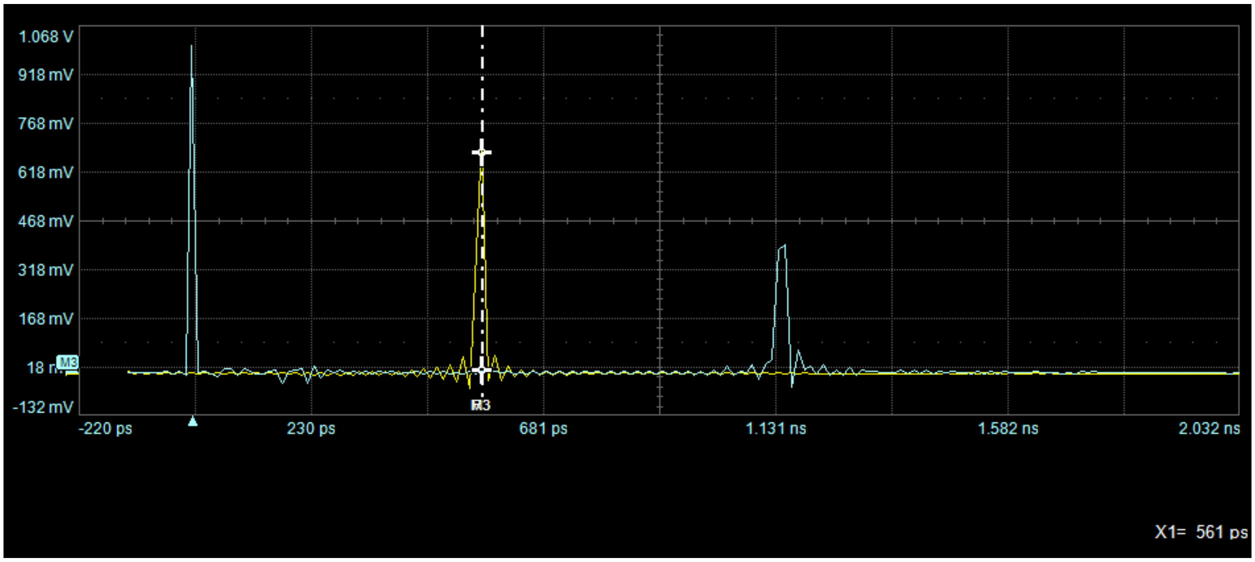


Figure 12: The S21 impulse appears at about 561 ps, indicating the delay can be increased by roughly 10 ps.

An additional way to fine-tune the delay is by performing gating on the measured 1X Open fixture. This de-embeds the fixture from the 1X Open measurement, and the residual delay or phase can then be used to update the value. The residual phase after gating is shown in Figure 13 below.

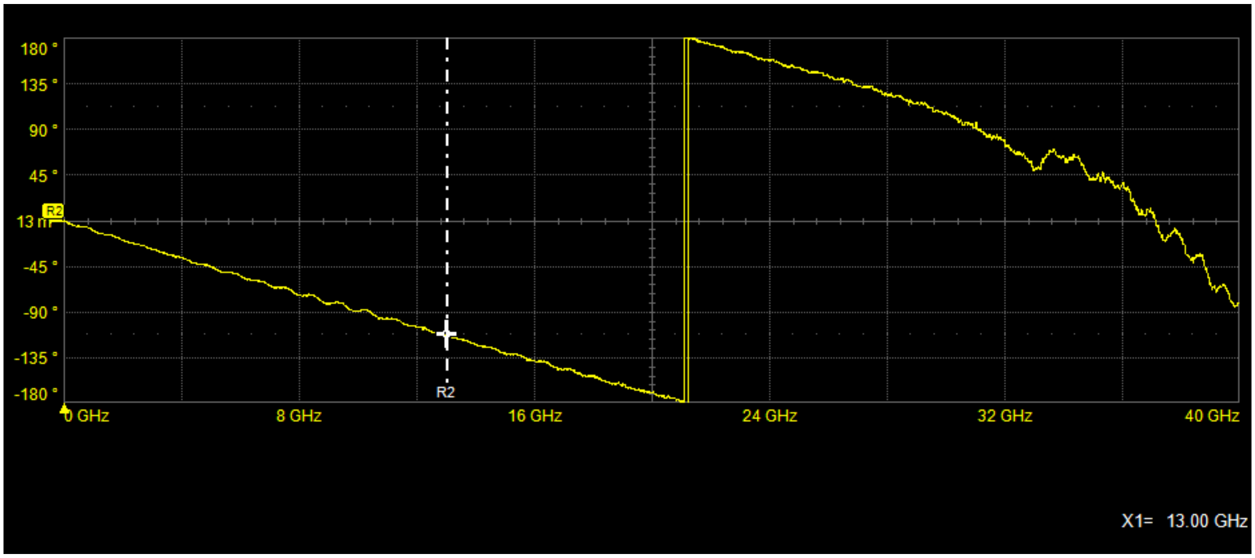


Figure 13: Residual phase after gating, used to fine-tune the delay parameter.

Given a straighter line between 12 GHz and 16 GHz, we can use a cursor to get the value of phase somewhere in between.

At 13 GHz, the phase is about −113°. Applying the linear relation for phase, $\omega T_d = \varphi$ where ω is $2\pi f_{in}$, T_d is the time delay and φ is the phase in radians. Here, the unknown is T_d, f_{in} is 13 GHz, and φ is the value measured by the cursor, or 113 degrees. After converting this in radians, we compute T_d as 24 ps. Since this is round-trip time, the residual length is half, or 12 ps.

These same residual S-parameters can also verify loss characteristics: S11 in dB should now appear as a flat line, as shown below in Figure 14. After 12 ps delay fine-tuning, the S21 impulse should precisely align between the two, open-reflection impulses.

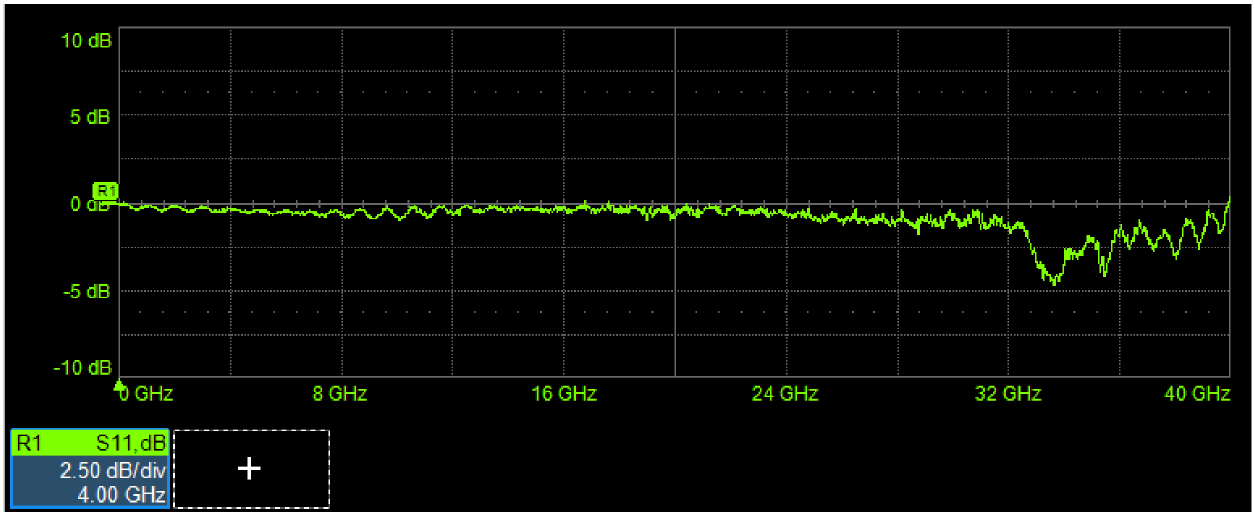


Figure 14: S11 in dB becomes flat after 12 ps delay fine-tuning of the delay

The gating parameters for linear Loss and sqrt Loss can be further adjusted to make the S11 dB flatter if desired. In Figure 14 above, the S11 dB looks reasonably flat and removing any more loss will now start to tilt the curve upwards (making it non-passive), indicating that too much loss has been removed.

Note that the residual here is not an ideal Short/Open. This occurs because we fit a model for the fixture to be de-embedded and then remove that model. A highly lossy or excessively long fixture can cause the model to diverge from reality, resulting in a residual that deviates from an ideal Short/Open.

Figure 15 shows the DUT + fixture measurement. The DUT is a stepped-impedance transmission line with the fixture connected to port 1. In the S11 impedance profile, both the fixture and DUT are visible, while the S22 profile, as expected, does not show the fixture at the start.

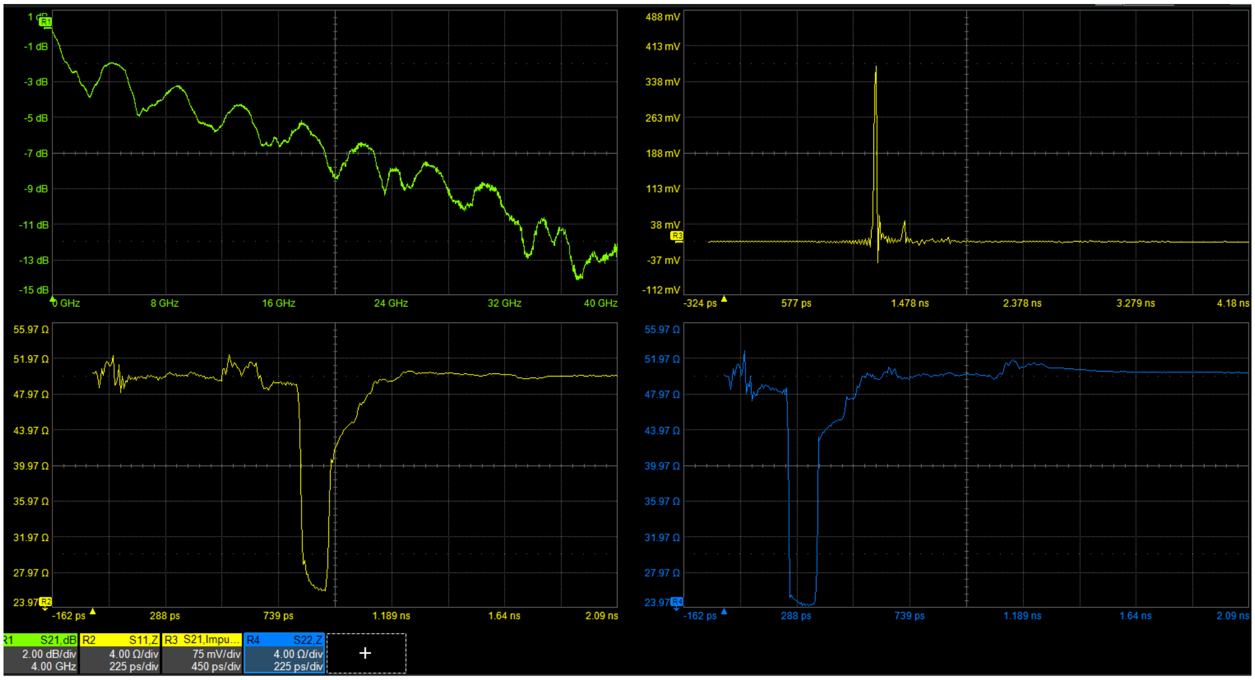


Figure 15: DUT + fixture measurement: In the S11 impedance profile, both the fixture and DUT are visible.

It is good practice to overlay the fixture S-parameters on the DUT + fixture S-parameters to verify port numbering. In the next plot, we store the DUT + fixture S-parameters in memory and recall the 1X Open measurement. This allows comparison of the impedance profile to confirm alignment before the open occurs. The plot in Figure 16 compares the S11 impedance profile from the 1X Open with that of the DUT + fixture measurement

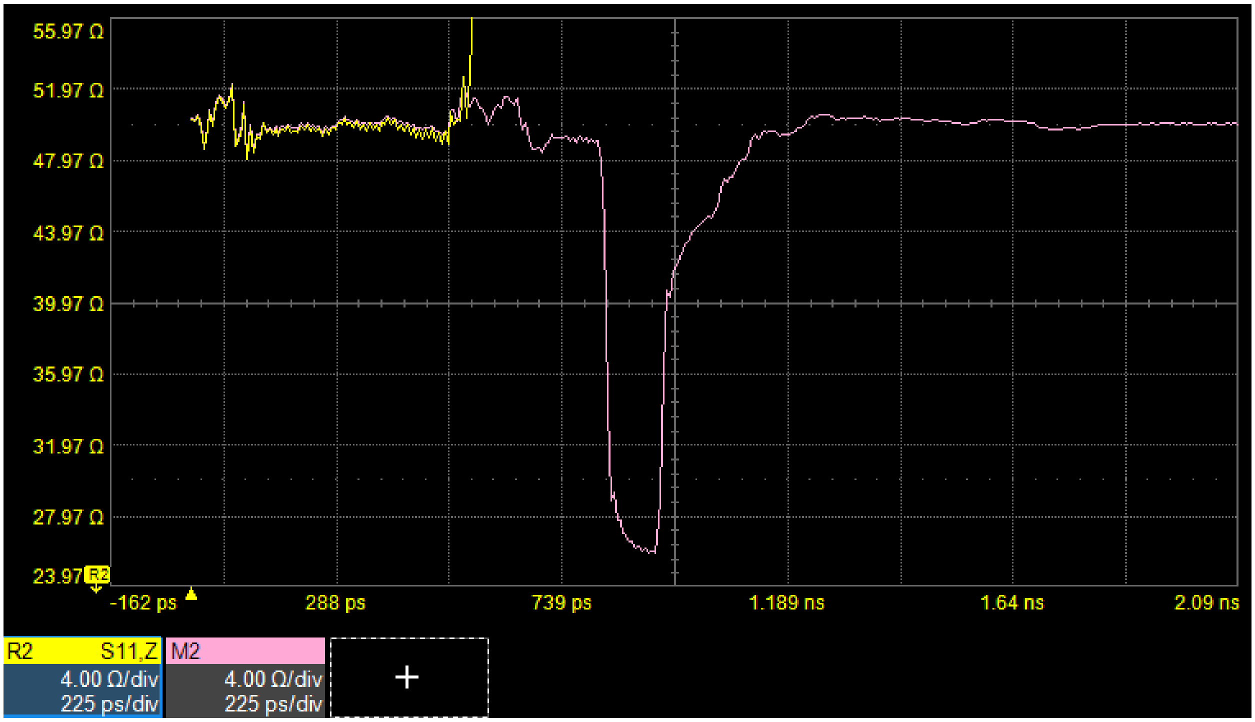


Figure 16: S11 impedance profile of 1X Open (yellow) vs. DUT + fixture (violet)

The impedance profile confirms the fixture length, though minor variations may occur since these are distinct physical structures. Using the previously fine-tuned gating parameters, we now gate out the fixture to obtain the DUT S-parameters. This allows comparison between the de-embedded measurement and the direct DUT measurement, as shown in Figure 17.

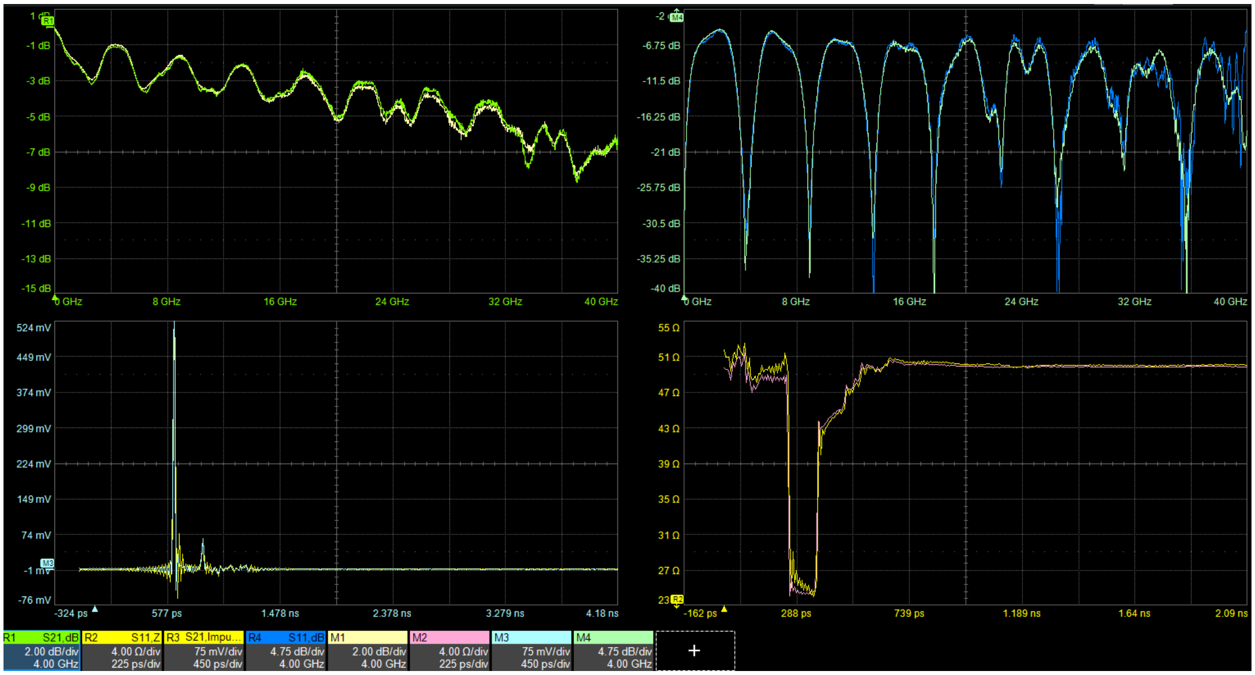


Figure 17: Comparing the de-embedded measurement to the direct DUT measurement.

The recommended fine-tuning process is summarized below:

1. Observe the phase to refine the length value and confirm that impulse response plots indicate a consistent length.
2. Loss values are computed using least squares fit on the measurement. The coefficients in gating menu are adjusted for length. Since length was fined tuned earlier, update the coefficients using the expression:

$$a_{new} = a_{old} \frac{length_{old}}{length_{new}} ,$$

   where a_{old} is the coefficient (loss or sqrt loss term) output by the 1xShortOpen algorithm, $length_{old}$ is the length (in ns) output by 1xShortOpen algorithm and $length_{new}$ is the new length (in ns) after fine-tuning.
3. Validate length and loss by reviewing residual S11 in dB and residual phase (or impulse response) after applying gating to the 1X Short/Open fixture measurement. While looking at the residual, disable passivity and causality checks—passivity can mask excessive loss removal, and causality can hide length-tuning errors that may appear in dB plots.

2X Thru with Gating

The concept of 2X Thru with Gating combines the 1X Short/Open approach with the fixture splitting described in the application note, "Mastering WavePulser 40iX 2X Thru De-embedding". In traditional 2X Thru, the fixture is divided into two halves so that cascading them reproduces the original measurement. Here, we fit a gating model to each half, and the resulting S-parameters can be cascaded to approximate the original data. Since the gating model is an approximation, de-embedding will not yield a perfect thru, but it effectively represents the fixture when the 2X Thru fixture differs from the DUT + fixture.

A 2X Thru fixture measurement is shown in Figure 18 below.

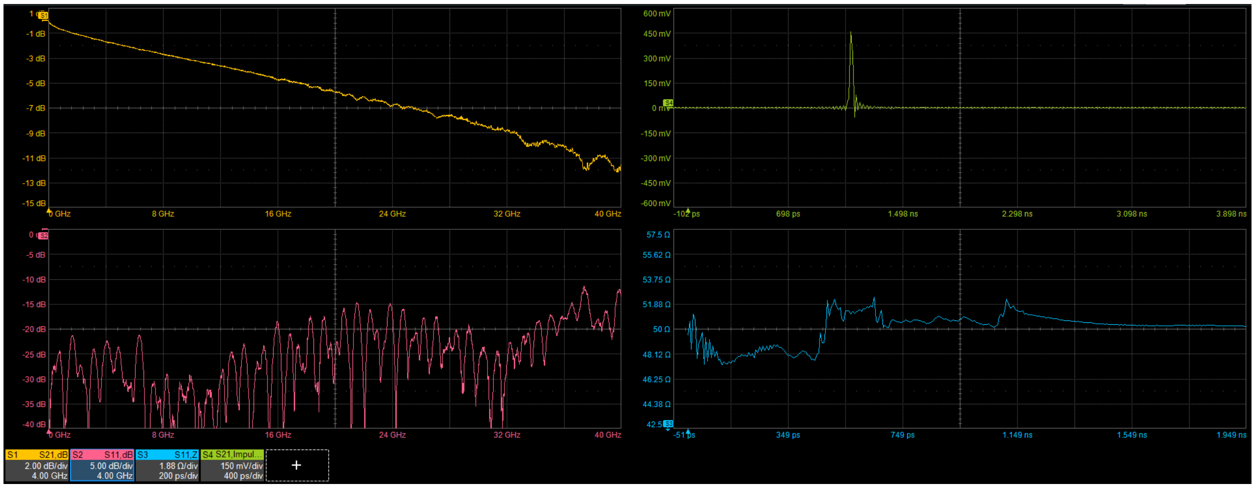
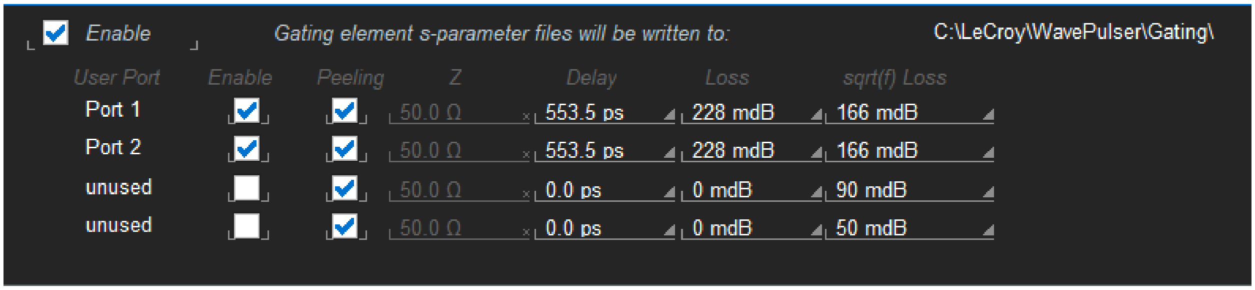


Figure 18: A traditional 2X Thru fixture measurement

Similar to the 1X Short/Open process, once we extract the gating parameters and apply them to this measurement, the residual fixture remains.

Figure 19 below shows the gating parameters and Figure 20 the resulting residual S-parameters.



☑ Enable

Gating element s-parameter files will be written to: C:\LeCroy\WavePulser\Gating\

User Port	Enable	Peeling	Z	Delay	Loss	sqrt(f) Loss
Port 1	☑	☑	50.0 Ω	553.5 ps	228 mdB	166 mdB
Port 2	☑	☑	50.0 Ω	553.5 ps	228 mdB	166 mdB
unused	☐	☑	50.0 Ω	0.0 ps	0 mdB	90 mdB
unused	☐	☑	50.0 Ω	0.0 ps	0 mdB	50 mdB

Figure 19: Gating parameters for a 2X Thru with Gating single-ended measurement

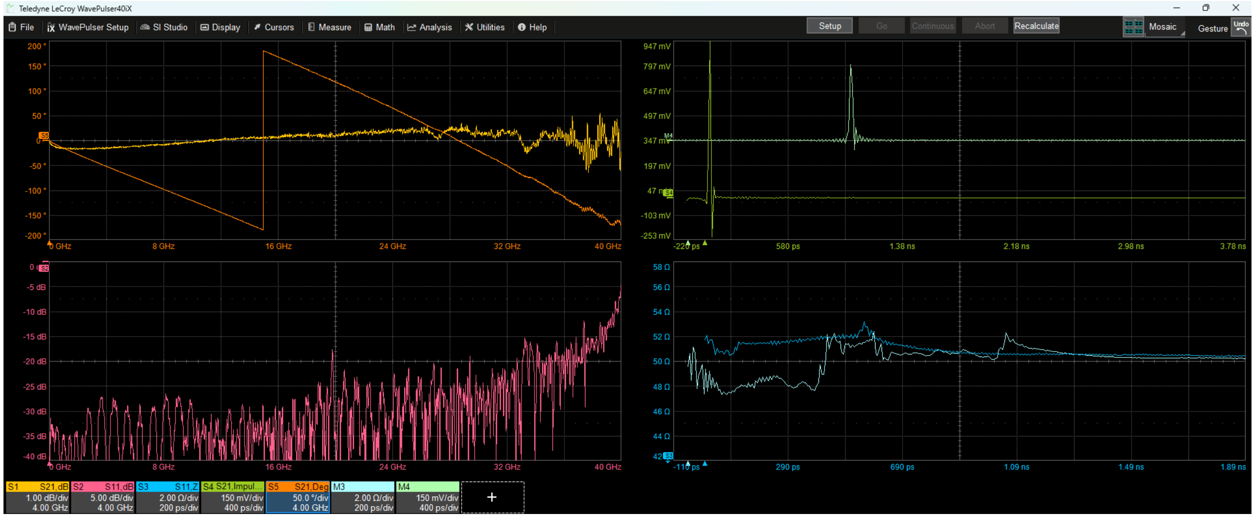
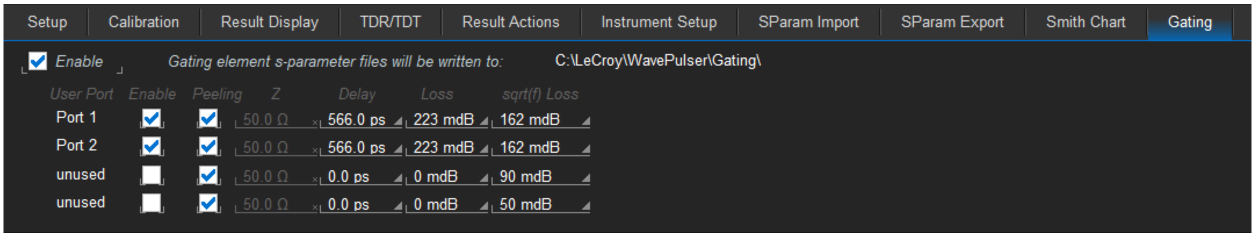


Figure 20: Resulting residual for the 2X Thru with Gating single-ended measurement

In Figure 20, S21 in degrees has been added to the plot, and passivity/causality enforcement removed to reveal the true residual. The S21 phase indicates residual delay that requires fine-tuning. A phase of 121.2 degrees at 10 GHz corresponds to a total delay of ~33.6 ps, or ~16.8 ps per half.

The S21 magnitude in dB shows that at low frequencies, some loss could have been further removed (curve below 0 dB), while at high frequencies, excess loss was removed (curve above 0 dB). This is a result of using a least-squares fit for loss, which we consider the most accurate modeling approach. If you prefer a different adjustment, fine-tune the two loss parameters accordingly.

After fine-tuning the delay by adding 12.5 ps (one-point delay) and adjusting the loss values through rescaling as outlined in point 2 on page 8 of this application note, the resulting gating parameters are shown in Figure 21 below.



☑ Enable

Gating element s-parameter files will be written to: C:\LeCroy\WavePulser\Gating\

User Port	Enable	Peeling	Z	Delay	Loss	sqrt(f) Loss
Port 1	☑	☑	50.0 Ω	566.0 ps	223 mdB	162 mdB
Port 2	☑	☑	50.0 Ω	566.0 ps	223 mdB	162 mdB
unused	☐	☑	50.0 Ω	0.0 ps	0 mdB	90 mdB
unused	☐	☑	50.0 Ω	0.0 ps	0 mdB	50 mdB

Figure 21: Fine-tuning delay and adjusting the loss for 2X Thru with Gating single-ended measurement

Applying these gating parameters, we are now left with the residual as shown in Figure 22 below.

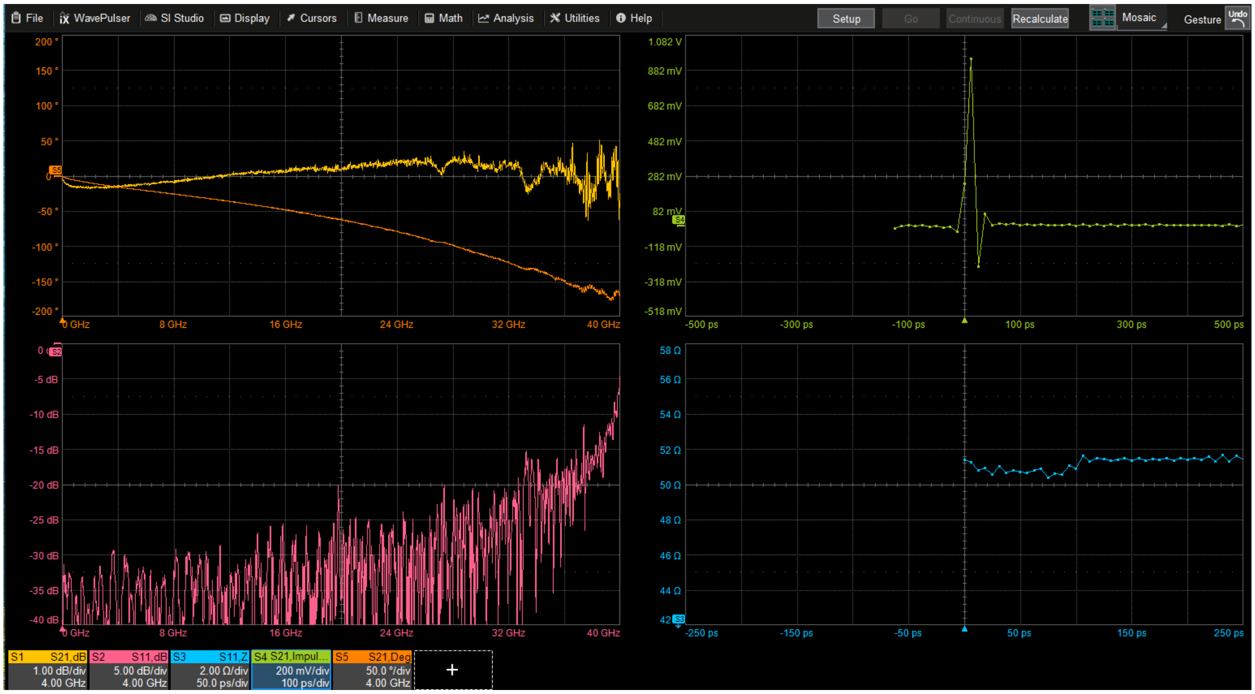


Figure 22: Resulting residual after fine-tuning for the 2X Thru with Gating single-ended measurement

The phase still shows residual values, but it is no longer linear. Examining the impulse response of the residual S21 reveals that at 0 ps, the response is already rising. Removing additional delay would render the fixture non-causal. The residual loss remains essentially unchanged, as we continue to use the least-squares fit values.

We can now compare the fixture derived through gating with the one obtained using the splitting method, as illustrated in Figure 23.

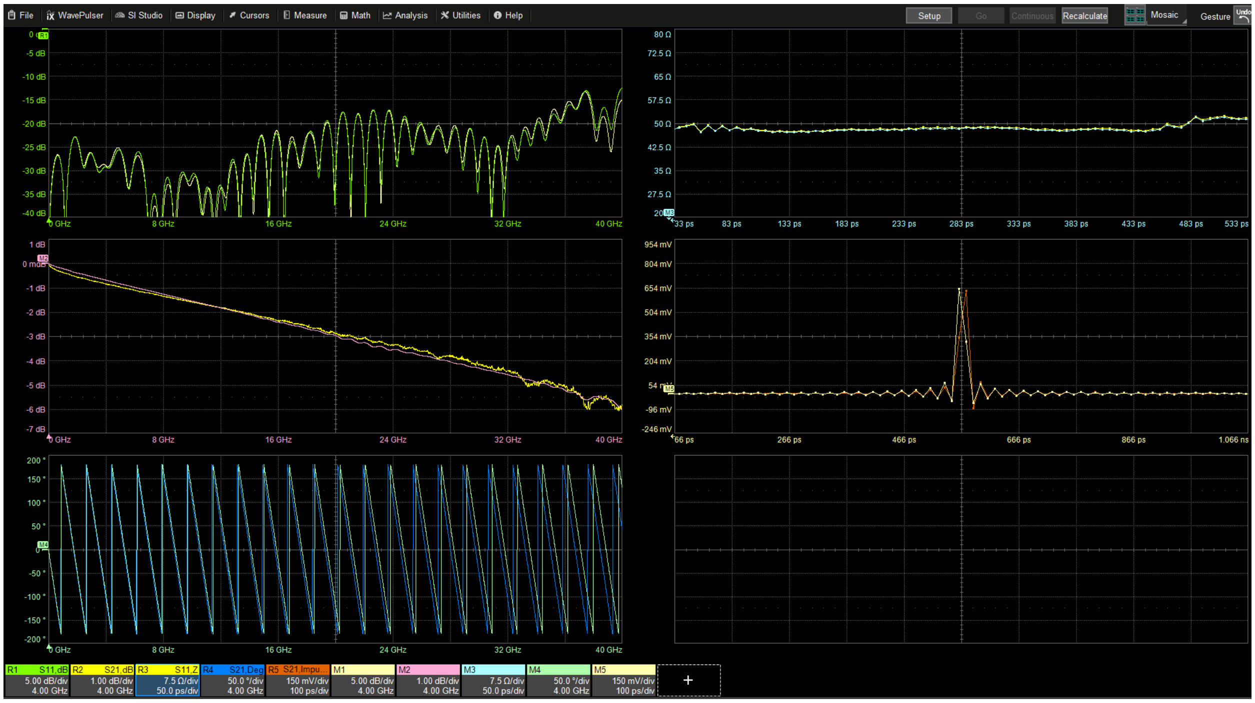


Figure 23: Comparison of 2X Thru with Gating vs. 2xThru splitting method

In Figure 23, the memory traces represent the gating method, while the R traces correspond to splitting. S11 shows excellent agreement in both the frequency domain (dB) and time domain (impedance profile). S21 exhibits slight differences, primarily because gating applies a specific model: linear in frequency for phase, and a combination of linear and square-root terms for magnitude in dB. As seen in the comparison plot, S21 magnitude from splitting does not fully align with this model. The phase matches well up to ~16 GHz, after which small deviations accumulate—again due to the linear phase assumption in gating. The non-linear shape observed in the residual phase highlights limitations inherent to our modeling assumptions.

Recommendations for Using 1X Short/Open and 2XThru With Gating

- The 2X Thru structure is a passive, reciprocal and causal device. Therefore, choose to Enforce Passivity, Enforce Reciprocity and Enforce Causality on the WavePulser Main Setup dialog when setting up the structure measurement.
- For both methodologies the gating parameters generated by the algorithm may not be fully accurate initially. We anticipate fine-tuning these parameters by leveraging WavePulser's TDR-based technology to avoid excessive correction.
- For 4-port fixtures, mode conversion is ignored. Designing fixtures that meet this criterion will help with accuracy.